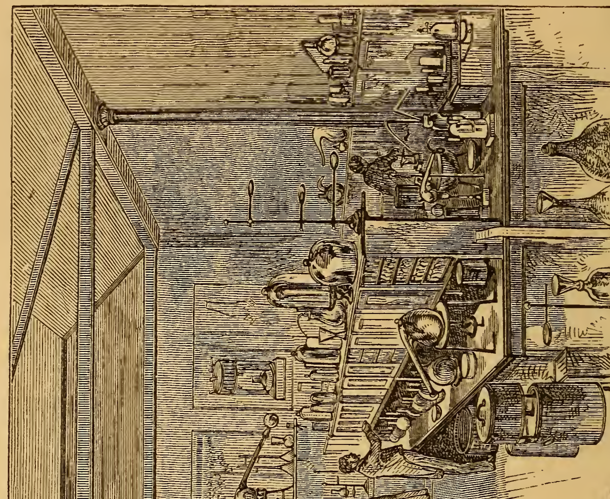

REVISED EDITION.

FIRST BOOK

IN

CHEMISTRY.

FOR THE USE OF

SCHOOLS AND FAMILIES.

By WORTHINGTON HOOKER, M.D.,

AUTHOR OF "CHILD'S BOOK OF NATURE," "CHEMISTRY," "NATURAL HISTORY," ETC.

With Illustrations.

NEW YORK:

HARPER & BROTHERS, PUBLISHERS,

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1877.

PREFACE.

The idea of this book was suggested by a lady, who is a stranger to me, in a letter, a portion of which I will quote here. "I can not tell you how much pleasure I have had in teaching the Child's Book of Nature to my little daughter. In giving my own opinion of that work I am also expressing the opinion of several other mothers of my acquaintance, who agree with me in pronouncing it the very best book of the kind which we have ever found. It is so plain and simple in its arrangement, that any child of common capacity can learn it with ease and remember it well. The subjects upon which it treats are of a kind to interest all children, and the pleasant way in which you bring them forward is sure to awaken their powers of observation and comparison, and, better still, to lead them 'through Nature up to Nature's God.' It seems to me that an elementary book on chemistry, upon the same plan, would be interesting to children, especially if they could have some simple and safe experiments which they might try for themselves."

Soon after receiving this letter, I put the matter to a test in the following manner: I selected a few of those school-rooms in the public schools of New Haven in which the scholars were from eleven to thirteen years of age. I visited these rooms from time to time, talking to the pupils for half an hour on chemistry, without trying any experiments, but illustrating the subject largely from common every-day phenomena. At each visit I questioned them upon what I had told them at the previous visit, and allowed them to ask me questions. In this way I found out what they could understand, and what they wanted to know, about chemistry. I was surprised to see how much of this science was within the reach of their capacity, and, at the same time, could be made very interesting to them. During all this time I jotted down my results, and at length put them into the shape in which they now appear, so that the book was almost literally made in the school-room. I may add that nearly the whole has been subjected to the examination of one of the teachers whose rooms I visited, a lady to whom I am indebted for many valuable suggestions.

This book can be readily comprehended by pupils of average capacity of twelve or even eleven years of age, especially if they have gone through with my Child's Book of Nature, which it is intended to follow. At the same time, it is fitted for older scholars to whom the subject of chemistry is entirely new.

I need hardly say that there must be carefulness in experimenting, and that some of the experiments described in this book should be tried only by teachers, or by pupils under their supervision.

This book is followed by three other books for the next higher grade of pupils. They are under one title—Science for the School and the Family. Part I., Natural Philosophy. Part II., Chemistry. Part III., Mineralogy and Geology.

WORTHINGTON HOOKER.

PREFACE TO THE SECOND EDITION.

In preparing a revised edition of this work no alteration has been made in its general plan; a considerable diminution in size has been effected by general condensation, but it is believed that no leading features have been omitted.

In adapting the nomenclature to modern theories and usage a compromise has been attempted, and a change made which some may regard as not sufficiently radical; but it has not seemed desirable to introduce the nice distinctions in terminology which are correlated to philosophical views, inasmuch as an explanation of these views is precluded by the very elementary character of the work.

The presentation of scientific truths to the youthful mind in a simple and attractive manner was the peculiar faculty of the author, and the editor has endeavored to preserve this characteristic, and to avoid burying the subject beneath the exactions of a scientific nomenclature.

H. Carrington Bolton, Ph.D.

School of Mines, Columbia College,
New York, *September*, 1876.

CONTENTS.

THE FIRST BOOK IN CHEMISTRY.

CHAPTER I.

THE CHEMIST.

What chemists do. Their discoveries.

In this book you are to learn about chemistry. But what is chemistry? you will ask. This we will explain to you in part in this chapter; but you can not understand fully what it is till you become well acquainted with what this science can show you.

You see represented in the frontispiece a large room with a great many different kinds of vessels and instruments and apparatus. There are several persons, chemists, engaged in trying experiments. Their object is to find out of what things different substances are composed, and what effects will be produced when they are mixed.

Chemists have discovered many things which will surprise you. You are in the habit of regarding each of the substances that you see all about you as made up of one thing. The chalk with which you mark on the blackboard you think of as chalk, and that is all. But the chemist has discovered that chalk is made of three things put together. One of them is a gas as thin as air. In fact, it is a gas that forms a part of the air which you breathe. Another is carbon, or charcoal. Yes, the charcoal makes a part of the white chalk; but it is not black now, because it is united with other things. The third thing in chalk is a metal. A gas, charcoal, and a metal, then, three things very unlike each other, unite to form chalk.

Then consider water, for example. Water, simple water, that surely, you will say, must be one thing. People used to think so—old philosophers as well as common people and children. But chemists have found out that it is not so. Water is composed of the same gas as that in chalk, united with another gas sometimes used for filling balloons. These two gases are continually uniting to form water all around you. This is going on in every fire and every light that you see burning. In every flame you see, whether it be flame of wood, or candle, or gas, or kerosene, these two gases are busy uniting together to form water. You do not see the water, for as fast as it is formed it flies off into the air. It makes a part of the water in the air, which is so finely divided that you can not see it, as explained in Chapter XIX. of the Third Part of the Child's Book of Nature. But you can catch this water thus formed in the flame as it flies off, and make it to be seen. One way in which you can do this is represented in Fig. 1. Ice and salt are in the bowl, the object of which is merely to make the bowl very cold.

Fig. 1.

The bowl is held so far above the candle that the soot will not gather upon it. Now, the finely divided and heated water flies up, strikes against the cold bowl, and is condensed upon it. A large drop of water therefore hangs, as you see, from the bottom of the bowl, fairly caught and brought to view.

You can do the same thing with a silver spoon or a glass goblet, if it be cold. Held over a candle or lamp, moisture will gather upon it. You do not catch so much water in this way as with the bowl of ice and salt, because the surface is not so cold, and is smaller.

Any thing which you try in a similar way is an experiment. Chemists are making experiments all the time, and by looking closely at the results they learn many new things. Experiments have proved that water is *composed* of two gases. Now, when the chemist takes some water and separates one of the gases in it from the other, we say that he *decomposes* the water. He does just the opposite of what is done in flame, for there the two gases come together to form water. So, when he separates the ingredients of chalk from each other, he decomposes the chalk.

We shall tell you, in other parts of this book, much more particularly about these and a great many other wonderful things.

Perhaps you have thought that you are too young to know any thing about chemistry, and that none but older and wiser persons can understand it. But this is not so. There are a great many things in chemistry that you can understand as well as the wisest man on earth.

Chemistry will be interesting to you because it tells about so many things that you see every day. You have very likely been in the habit of thinking that the chemist is engaged in finding out only about things which have hard names, and that you have nothing to do with. But it is far otherwise. Very many things that he can tell you about are the commonest of all things. We have already spoken of chalk and water. Then there is the air you breathe—you will like to know about that. The chemist can tell you what part of the air keeps you alive, and how it does it. You will be surprised to learn that some of the air is continually becoming a part of your body, your flesh and bones, and that some of your body is all the time turning into air and flying off all around you. But so it is, as we shall by-and-by show you.

Chemistry will tell you how fires and lights burn.

Chemistry will tell you what it is that makes bread rise, and how it is that the grain from which it is made is fitted in growing to nourish your body.

It will tell you how wine is made from grapes and other fruits, and explain what that is in the making of cider and beer which is called *working*. It will explain, too, the making of vinegar.

It will tell you how soaps are made, and explain the way in which they operate in cleansing clothes and freeing things from dirt.

It will tell you about the making of different paints and dyes.

It will tell you also how to find out if the things you eat and drink are pure, or whether substances are mixed with them which are not fit for food.

You hear a great deal about the experiments that the chemists try. In this book we shall tell you of many experiments that you can try for yourselves. You can try them with bottles and tubes that you can buy with a very little money, and many of them you can try by using a little ingenuity even with things that you can find about the house.

But you will not need to do even this to be interested in chemistry, because there are things happening before you continually that illustrate the subject. There are experiments, as we may say, going on all around you and even within you; and you have only to look and to think, to get chemistry out of the commonest things. Every time that you rub a match, or set fire to gas, or light a candle or a kerosene lamp, you make a chemical experiment. Every time you draw a breath, you make chemical work for your lungs. Every time you eat, you set in motion in your stomach some of the chemical operations that the chemist in his laboratory or work-room makes in some of his queerly-shaped glass vessels. And your body is kept warm, as we shall show you in one of the chapters of this book, by a sort of chemical fire in you—a fire without a flame.

Questions.—What are chemists? Of what is chalk composed? Why is not the charcoal black in the chalk? What did all people use to think about water? What have the chemists found out about it? Tell about the formation of water in flame. Why do you not see the water that is formed? How can you catch the water as it flies off? What is decomposition? Why can you expect to understand much about chemistry in studying this book? Why will chemistry be interesting to you? What things will chemistry show you about air? What can the chemist tell you about bread? What other things will chemistry explain to you? What is said about experiments?

CHAPTER II.

OXYGEN.

Oxygen. That is a hard word, you will say. Why hard? Simply because it is new, and you do not understand what it means. When we have told you what oxygen is, and related to you the interesting facts about it, the word will be as easy to you as any other word of the same length of which you know the meaning. The names of many of your acquaintances would be hard words to you if they were not the names of those whom you know. Now, we hope to make you as well acquainted with oxygen as you are with any of your friends, and then it will be quite as easy a name to you as Ellen, Henry, or Gertrude. Many words which you use every day are much longer than oxygen, such as amusement, dissatisfaction, experiment, etc.; but they are easy to you, because you know what they mean.

Though you are not yet acquainted with oxygen, you have a great deal to do with it. Indeed, you could not have done without it at any moment since you were born. Every time you draw a breath you take some of it into your lungs, for there is always oxygen in the air. If what there is in the air should be taken out of it, you would die as quickly as if you were under water.

This oxygen is part of the food which nourishes your body. It does not, it is true, go into your stomach, but still it is just as necessary for your body as the food you swallow. It is food for your lungs, and your lungs must have it, or you will die.

The food that you put into your stomach you can do without for some time. You can live without it even for days; but the lung-food you must have every minute.

The food that enters your lungs helps to make up the solid part of your bodies—your bones, muscles, skin, etc. But it is not solid when it goes in. It is a gas. There are a great many different kinds of gases or airs. The air you breathe is a mixture of three of these gases. The gas we burn is very different from that we have in the air. If you live in a village, perhaps you never saw gas burning from a gas-burner. But you see a gas burning when you see a flame of any kind, whether it comes from wood, a candle, or a lamp. The oil or tallow is changed into gas before it burns. What we call flame is burning gas. When wood or coal is burned, all except the ashes goes off into the air, and burns as it goes.

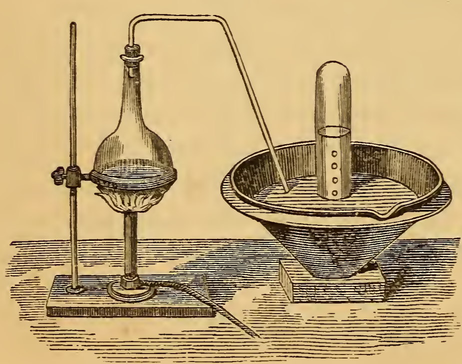
Most gases have no color, and you can look through them as you look through glass. You are always looking through gases, for the air is a mixture of three gases. You can not see the air, and so you can not see any gas that has no color. For example, if a gas-burner be left open without being lighted, you can not see the gas coming out, although you can smell it. The colorless gases are said, then, to be *transparent*, like clear glass, because objects are seen or *appear through* them, *trans* being a Latin word which means *through*.

We shall tell you about many gases in this book, but first we must speak particularly of oxygen.

Oxygen, besides being a part of the air, forms a part of almost every thing you see. It forms a large part of all the water in the world. It is in your skin, and muscles, and bones, and every part of your bodies, and is an important part of the blood that runs in your veins and arteries. It is in all animals and all plants. It makes a part of the ground beneath your feet, and even the solid rocks are made in part of oxygen. This gas is the most abundant substance in the world.

It may seem strange to you that so light and thin a substance as gas can make a part of any solid, as flesh or bone. But you see every winter a liquid become solid, for ice is solid water. Now, this same water, which is sometimes liquid and sometimes solid, is sometimes also as thin as air or gas. There is always some water in the air, even when it seems to be very dry; and as in the clear air that seems so dry there is no water to be seen, the water must be as thin as the air itself. It is no more strange that oxygen gas can become a part of a solid, than that this water, as thin as gas, can be turned into solid ice.

Fig. 2.



Oxygen gas can be separated from some of the substances with which it is united, and so can be obtained by itself. The chemist commonly uses for this purpose a certain powder. What this powder is we will not tell you now, but shall notice its composition in another book, when you can understand it better than at present. This powder is heated in a glass flask, by a gas lamp placed underneath, as represented in Fig. 2, on the opposite page. The oxygen, separated from the powder by the heat, passes over through the small tube, connected with the flask by a cork, and bubbles up from the end of the tube which dips under the water in the earthenware vessel. Over the end of the tube a glass vessel is placed, with its open end down. This jar is full of water at first, the water being kept in it by the pressure of the air on the surface of the water around it, as explained in the Child's Book of Nature, Part III., Chapter IV. As the end of the glass tube is put under the mouth of the jar, the gas goes up in bubbles through the water, because it is lighter than water, and takes its place in the upper part of the jar. In this way the jar may be filled with the oxygen gas. When you want to use the gas for experiments you may remove the jar carefully, placing a piece of window-glass under the mouth of the jar to keep the gas from flying out.

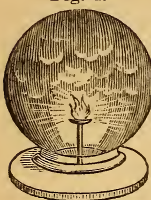
Fig. 3.

Many beautiful experiments can be tried with oxygen.

Put a lighted candle into a jar of oxygen, as in Fig. 3. It will burn with a dazzling brightness, and will be rapidly consumed. The reason is this. It is the oxygen in the air that makes the candle burn at all. Of course, the more oxygen gets to the candle, the more brightly it will burn.

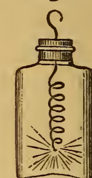
In the same way, a piece of charcoal, or of sulphur lighted and plunged into a jar of oxygen, burns much more brightly than in the air, but no substance burns in oxygen with so brilliant a light as phosphorus, Fig. 4. A very thick white smoke arises, which is most brilliantly illuminated.

Fig. 4.



Some substances, which most people think can not burn at all, burn very readily in oxygen. Iron is one of these. If you take a piece of steel wire, and twist it as shown in Fig. 5, you can make a splendid fire with it in the oxygen. But how will you manage it? You can not set it on fire in the air, and then introduce it into the oxygen, as is done with the phosphorus, on the candle. It is managed in this way. The end of it is dipped in sulphur, or has a bit of something which will burn in common air fastened to it, as cotton or charcoal. You light this substance, and then introduce the wire into the jar of oxygen. The substance on the end of the wire, in burning, sets fire to the wire itself, and then the sparks fly very prettily.

Fig. 5.



Questions.—What is said about the word oxygen? What would happen to you if you could not get any of it into your lungs? What is said about oxygen as food? What does oxygen gas help to make in your body? Of what is the flame in a candle or lamp made? What is said about gases being transparent? Mention some of the things in which there is oxygen. What is said about its making a part of solid substances? Tell about obtaining oxygen gas. Describe and explain the experiment with a lighted candle. How does phosphorus burn in oxygen? Describe the way in which a steel wire burns in oxygen.

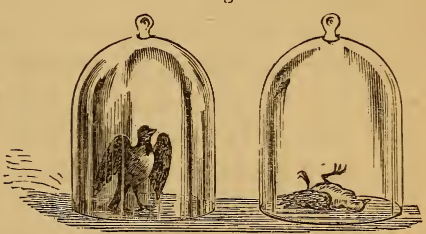
CHAPTER III.

NITROGEN.

To every gallon of oxygen in the air there are about four gallons of another gas called nitrogen.

This gas is very different, in some respects, from oxygen. Nothing will burn in it. If you put a lighted candle into a jar of oxygen, it will, you know, burn more brightly than it does in the air. But if you take it out of the oxygen, and put it into a jar of nitrogen, it will go out. Not even phosphorus will burn in nitrogen. So, if all the oxygen should be taken out of the air, every fire and light would be extinguished.

Fig. 6.



Besides this, no animal can live in nitrogen gas. If you put a bird into a jar of oxygen, it will be more lively than in common air, and will act as if crazy, jumping about in the most singular manner; but if you should put it into a jar of nitrogen, it would die at once. And if all the oxygen should be taken out of the air, all animals would die, just as all the fires and lights would be extinguished.

But this nitrogen gas does not really put out fires and lights. A light, when placed in a jar of nitrogen, goes out merely because there is no oxygen. If you mix a little oxygen with the nitrogen, the candle will burn, just the same as in common air, which is really a mixture of oxygen and nitrogen.

So, too, nitrogen does not kill any animal, although he can not live in it. It does not act as a poison when it goes into the lungs; for four times as much nitrogen as oxygen enters the lungs of animals, all the time. The bird dies in the jar of nitrogen simply because nitrogen can-not keep it alive.

Of what use, then, is the nitrogen in the air, as it does not help to make any thing burn, or keep any thing alive? We will tell you.

Suppose the air were all oxygen, instead of being a mixture of oxygen and nitrogen. What would happen? You can see by calling to mind the experiments in which different things were burned in jars of oxygen. Our fires and lights would burn very brightly. This would sometimes be quite convenient. We should not be troubled with dull fires and dim lights. It would be one of the easiest things in the world to kindle a fire. But then, on the other hand, there would be a great deal of inconvenience and danger from so much oxygen. Things would burn too fast. We should have things taking fire much oftener than now; and when a fire once started it would be very hard to put it out. If a block of houses should take fire at one end, the whole block would be burned. Whole towns and cities would often be destroyed.

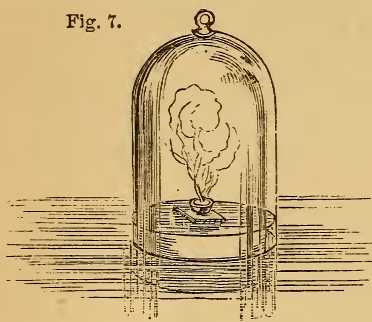
Besides all this, if the air were wholly oxygen it would be injurious to animals. It would be too heating, too stimulating. With so much oxygen going into our lungs, we should be all the time as warm as we are after exercising violently. This would make us very uncomfortable. We should be forever fanning ourselves, and drinking cold water, and seeking for cold air. Inflammations and fevers would be produced, and we could not live long in this way.

It is chiefly for these reasons that God has given us our oxygen mingled with so much nitrogen. It is very much as we take some medicines. They are put into sugared water because it would not be agreeable for us to take them clear. The sugared water is to the medicine as the nitrogen is to the oxygen. Suppose the medicine is some strong acid. It would make your mouth sore if you should take it clear, so we *dilute* it, as we say, with sugared water. In like manner, the oxygen is diluted with nitrogen, that we may take it into our lungs without harm.

Nitrogen, you see, is a very mild gas when free, as it occurs in the air. But when it combines in a chemical way with oxygen, it forms very dangerous gases, quite unlike the air. Nitrogen also forms a part of all animals, as well as some parts of vegetables. It is also one of the two ingredients of ammonia, or hartshorn, which tingles your nose whenever you smell it.

You can get nitrogen gas from the air by a very pretty experiment. All you need is a basin of water, a glass jar, a flat cork smaller than the mouth of the jar, and a bit of phosphorus. Hollow out a little place on the cork and float it on the basin of water. Then with pincers pick up a piece of phosphorus about the size of a pea, and place it on the cork. If you touch the phosphorus with your fingers, you may burn them badly. Now

Fig. 7.



set fire to the phosphorus as it floats on the cork, and put the jar over it with its edge in the water. Think, now, what you have in the jar. There is a mixture of oxygen and nitrogen, that is, air. Then you have the burning phosphorus. Now, oxygen is there. If there were nothing but nitrogen in the jar, it would not burn at all. If you watch the experiment, you will see that, after a little while, the phosphorus burns rather dimly, and at length goes out, although there may be considerable phosphorus left. This is because the oxygen is all gone, and there is nothing now but nitrogen in the jar.

You will see that the cork has risen in the jar, being pressed up by the water. Why? The part of the air in the jar which is oxygen is used up, and so makes room in the jar, and the water and cork are pressed up to fill this room. One-fifth of the air in the jar is gone, for oxygen forms one-fifth of the air.

But what has become of the oxygen? It is not lost in the burning. It is united with the phosphorus, and they, together, make the white smoke which arises when phosphorus is burned.

This smoke soon disappears, for it dissolves in the water, forming with it an acid called phosphoric acid. Thus the nitrogen is left alone in the jar. In this experiment the nitrogen is not changed. The burning phosphorus does not unite with it, but takes all the oxygen out of its company. The phosphorus has a strong affinity, as chemists say, for oxygen, while it has none for nitrogen.

Questions.—What proportion of air is nitrogen ? Tell about putting a lighted candle in this gas. What would happen to the fires and lights if all the oxygen were taken out of the air ? Why does a light go out when put into nitrogen gas ? Why does an animal die when put into it ? Tell what would happen to fires and lights if the air were all oxygen. What influence would it have on animals ? Of what use is the nitrogen in the air ? What does the word *dilute* mean ? What is said about the character of nitrogen ? How would you arrange your apparatus for obtaining nitrogen ? Why does the phosphorus burn ? Why does the cork rise in the jar ? What becomes of the oxygen in the jar ? How is it that the nitrogen is left alone in the jar ? Is the nitrogen changed by the phosphorus in this experiment ?

CHAPTER IV.

NITRIC ACID AND LAUGHING-GAS.

In air, as you have seen, oxygen and nitrogen are only mixed together. The oxygen is diffused through the nitrogen as alcohol is diffused through water when they are mixed. But oxygen and nitrogen can combine in such a way as to form *compounds* that are very different from the mixture we call air.

One of these compounds united with water forms a very powerful acid called nitric acid. It will destroy cloth, and even flesh, if dropped upon it. How strange it is that such a biting acid is composed of water and two gases that are so quietly going into our lungs every time we breathe!

These gases, mixed so thoroughly in the air, have no disposition to unite together to form this acid. It is very difficult to make them unite. All the shaking which the air gets in violent winds and whirlwinds will not do it. Air is sometimes greatly heated, but the heat of the hottest furnace can not unite the oxygen and the nitrogen of the air. A flash of lightning, as it passes along through the air, will make them unite so as to form nitric acid; but only a little is made in this way. This little, however, being carried down in the rain, is of use to the farmer and the gardener in making things grow.

There is another compound of these two gases which is of a very different character from the nitric acid. It is in the form of a gas. It can be breathed, and it does not irritate the lungs. It produces, however, a very singular effect upon the system, greatly exciting the person who breathes it. Under its influence different persons act very differently. One, perhaps, bows and smiles continually; another dances; another laughs; another declaims with great eloquence; another wants to fight—and so on. The delirium lasts but a few minutes; and when the person recovers, he does so all at once, and seems to be half ashamed of what he has been doing.

Now, a person in breathing this gas takes into his lungs oxygen and nitrogen, as he does when breathing air; but they are not merely mixed, as in air, but form a compound, a new thing, different from both the oxygen and nitrogen. Neither nitrogen nor oxygen, nor their mixture in air, ever produces an intoxicating effect, as does their compound, laughing-gas.

Laughing-gas does not occur ready formed in nature; it is only made in the chemist's laboratory, by heating a certain white crystalline substance in a glass vessel, somewhat in the same way that oxygen is prepared. Before the gas is given to persons to breathe, it must be carefully purified by passing it through a solution of potash, and in other ways.

Observe how these two compounds, nitric acid and laughing-gas, differ from each other. One is a liquid which stains and corrodes. The other is a gas, soft and mild, but when breathed it makes people delirious. It so often makes them laugh, that this has given it its name.

The reason of the difference between the two lies in the different proportions of the ingredients. The nitric acid has a great deal more of oxygen in it than the laughing-gas.

Suppose that the oxygen and nitrogen in the air were very much disposed to unite to form compounds. What would happen? Suppose, for example, that once in a while these gases should unite in the air and make a large quantity of laughing-gas. In whatever country this should happen, all the people —men, women, and children—would be running about crazy, laughing, fighting, and playing all manner of strange pranks.

Or suppose that these gases should all at once unite to form nitric acid in the air. It would rain down upon the people, destroying the life of every animal and every plant, thus making the earth desolate.

But the Creator has so made these gases that they can not unite when they are mixed, and the air is one of the mildest and pleasantest of all the mixtures that he has given us. When, at the end of the creation, he pronounced all his works to be "very good," he meant the air as well as other things. It is good—very good—for all the purposes for which it is wanted.

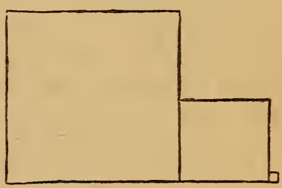
Questions.—Is air a compound? Of what is nitric acid composed? What is said of the difference between this and the gases that compose it? What of the difficulty of making these gases unite to form nitric acid? Tell about the effect of lightning upon them. Of what is laughing-gas composed? What are its effects when breathed? What is said of its being a compound? What of the difference between this compound and nitric acid? What is the cause of this difference? If the oxygen and nitrogen in the air were very ready to unite together, what effects would be produced? What is said about the creation of air?

CHAPTER V.

CARBON.

Thus far we have spoken of there being two gases in the mixture we call air. But there is a third gas, in very small quantity, in the air, called carbonic acid, or carbonic acid gas.* There is only one gallon of this gas in every 2500 gallons of air. The proportions of the three gases in the air may be illustrated by Fig. 8. The largest square represents the nitrogen; the next, the oxygen; and the very little one, the carbonic acid. Although there is so small a proportion of this gas in the air, it has a very important influence.

Fig. 8.



Carbonic acid gas differs from oxygen and nitrogen in being composed of two things. Neither oxygen nor nitrogen can in any way be divided. They are therefore called *elements*, or elementary substances. But carbonic acid is not an element, but a *compound*, for it is made of two things *united in one.* Observe that these two things are not *mixed*, as the two elements nitrogen and oxygen are, in the air; but they are *united* so

* This gas is also called carbonic anhydride, for reasons given in Science for the School and Family, Part II., second edition. In this book, we will call it simply carbonic acid.

as to make one thing in effect—as much one as if it were really an element. The two elements which compose carbonic acid are your lively friend oxygen, which you have become so well acquainted with, and another that we will now introduce to your acquaintance, carbon.

Carbon appears in various forms, but the most common is that of charcoal. It is for this reason that the two names, charcoal and carbon, are ordinarily used by chemists as meaning the same thing. The various kinds of coal we burn are chiefly carbon. Graphite, or black-lead, as it is called, is a form of carbon. It is this which is used in our lead-pencils. The name black-lead is very improper, for there is not a particle of lead in this substance. It is wholly carbon, with the exception of a very little iron which is generally present.

In the diamond we have carbon perfectly pure and beautifully crystallized. How strange that this most costly and brilliant of gems should be made of the same material with common dull and black charcoal! But so it is. And yet no man has ever discovered any way of changing charcoal into diamonds. The Creator alone knows how diamonds are made.

Diamonds are very expensive. Fifty dollars will buy but a small one. The largest one ever found is about the size of half a hen's egg. The famous one which now belongs to the Queen of England is less than half of the size of this, but it is valued at three millions of dollars.

Diamonds are found in the sands of rivers in Brazil, in Africa, and rarely in the United States.

The diamond is the hardest substance in the world. You can not scratch a diamond with any thing but another diamond; and in preparing a diamond for use as an ornament, it is ground with the powder of diamonds. The instrument with which the glazier cuts glass has a small diamond in its end.

All the different forms of carbon can be burned. Most of them burn in common air; but black-lead and the diamond will not. To burn them, you must have oxygen alone, without any nitrogen.

When carbon burns, it unites with oxygen, forming carbonic acid gas; this same gas results whether we use carbon in the shape of diamond, graphite, or charcoal.

It is rather an expensive experiment to burn up a diamond, and it is not often performed.

The charcoal we use is, you know, made from wood. It is wood partly burned. It is made by burning wood in a heap, covered up with turf and dirt. Small openings are left above and below, so that a little air can circulate among the wood, and thus keep up a smothered burning.

Wood is composed of carbon united with some other things; and when wood is burned just enough to drive out these other things, the carbon remains. If too much air gets to the wood, the carbon itself will burn too, and, uniting with the oxygen, will fly off in the form of carbonic acid gas. Wood, even though it may seem to be dry, contains considerable water, and this is driven off by the heat.

You can readily make charcoal in a small way. Take a test tube (Fig. 9, on the following page), and hold a burning slip of wood in it. The tube prevents the air from getting freely to

Fig. 9.

the wood, and makes a smothered burning, and so you have a slender piece of charcoal.

Hard coal is almost wholly carbon. It differs from charcoal in being very solid. It is supposed that all the coal that man gets out of coal-mines was once wood. How, then, did it become coal? Man can not make such coal from wood; but God can do a great many things that man can not do. But do we know how the Creator made this hard coal? We know something about it. We know that there must have been great heat and great pressure at the same time. While the wood was heated or partly burned, the rocks and earth above it were pressing down upon it, and so made the coal very solid.

Soot is mostly carbon. It is made up of little particles of carbon, which are thrown off from the burning wood, and lodge on the chimney's sides.

When a lamp smokes because the wick is too high, the smoke is made up of these little particles of carbon, for oil, as well as wood, contains carbon. It smokes because more oil rises in the wick than can unite with the oxygen supplied. If you could make the oxygen come to the wick faster, it would stop the smoking; for then there would be oxygen enough to turn all the carbon into carbonic acid gas.

The lamp-black much used in painting is a kind of charcoal. It is made by letting the smoke of burning pitch or rosin into a sort of chamber lined with leather, on the sides of which it collects.

There is much carbon in many very different things: it is in chalk and marble. It is combined in these with oxygen and lime; so that it does not show itself as carbon any more than in carbonic acid gas. It is in egg-shells, oyster-shells, and in all kinds of shells. It is in all wood, and makes an important part of all leaves, flowers, and fruit. Your body, and the bodies of all other animals, have carbon as one of their principal ingredients. But it does not show itself in them as carbon any more than in the white chalk and marble. It is hidden in them by being united with other things. By separating it from these things, it can be brought out from its concealment, and shown to be carbon, as is done when charcoal is made from wood.

Questions.—How many gases are there in the air? How much carbonic acid gas is there in it? What is an element? What elements are there in the air? Why is carbonic acid called a compound? What is the most common form of carbon? What is graphite? What is the diamond? What is said of diamonds? What is said of burning carbon? What is formed when we burn it? How is charcoal commonly made? What becomes of the water that is in the wood? How does hard coal differ from charcoal? How is it probable that it was made? Tell about soot. Why does a lamp smoke when the wick is high? What is lamp-black, and how is it made? Mention some of the substances that have carbon in them.

CHAPTER VI.

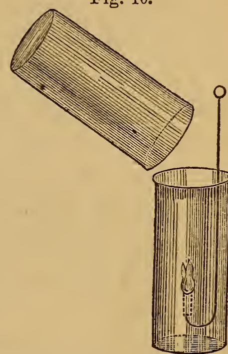
CARBONIC ACID.

Carbonic acid gas, as you learned in the previous chapter, is composed of the solid carbon and the gas oxygen. The solid is no longer a solid, but is united with a gas to form another gas; and then this gas thus formed unites with many substances to form solids. In marble, for example, this gas is combined with lime. Now, we can obtain carbonic acid gas from the marble by putting with it something which will take the lime away from it, and this is done by strong acids. There is an acid called hydrochloric, very corrosive, and sometimes fuming in the air; if you pour some of this, mixed with water, into a bottle, and throw in pieces of marble, gas will bubble up through the water, effervescing, as it is called, like soda-water. In a short time the bottle will fill with the gas, though you can not see it. To find out if the bottle is full, light a splinter of wood, and dip it into the apparently empty bottle. The gas extinguishes the flame, nor will a candle burn in the gas; so you see things will not burn in carbonic acid gas. Why does the candle go out in this gas? Because there is no oxygen there to make it burn.

As nothing can burn in this gas, so no animal can live in it. Put a mouse into a jar of it, and he will die at once. There is a little of this gas in common air, but so very little, that it does no harm to us or to other animals.

Carbonic acid gas is much heavier than air. You can therefore pour it, like water, from one vessel into another.

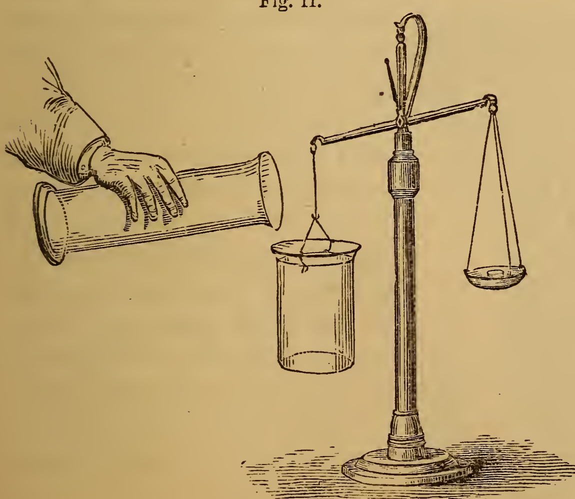
Fig. 10.



If you place a lighted candle in a jar of common air, and pour into the jar some of this heavy gas (as shown in Fig. 10), the gas will go down into the lower jar, forcing out the air and putting out the light.

Carbonic acid gas is heavy enough to be weighed. Perhaps you think it is not possible to weigh something which you can not see, but it may be done with the apparatus shown in Fig. 11. Balance a jar of air on the scales, and then pour into the jar some of the gas; the jar will then fall, and the weight will rise. This shows that the gas is much heavier than the air.

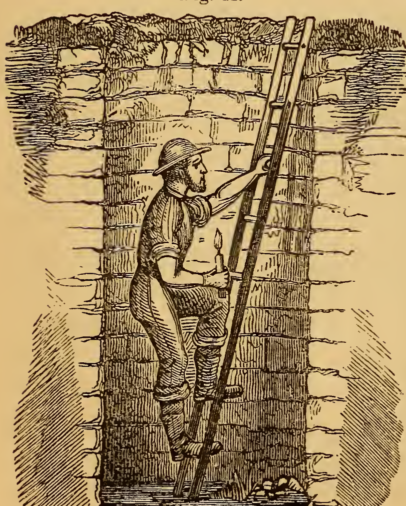
Fig. 11.



As carbonic acid gas is so heavy, it is apt to remain below air wherever it collects. It sometimes collects in considerable quantity in wells. When this is the case, it remains at the bottom of the well. Suppose a man goes down into such a well to clean it: he will have no difficulty at first, because the air is good—that is, it has enough oxygen in it, and not too much carbonic acid; but when he gets near the bottom, where the carbonic acid gas has accumulated, he gasps for breath, and falls. Perhaps some one, not understanding the cause of the trouble, goes down to relieve the man, and he also falls senseless. Many lives have been lost in this way.

Now, how can we find out whether this gas has collected in a well? Let a light down. If it goes out, there is a good deal of the gas there; and if it burns dimly when it comes near the bottom, there is enough of the gas to make it dangerous. A very good way is for the man who goes down a well to take a candle with him, as you see in Fig. 12. He must hold the candle considerably below his mouth, or it will do no good. If his light goes out, or becomes quite dim, he must stop at once, for another step would bring his head down into the gas, so that he would take it into his lungs.

Fig. 12.



To get rid of the gas, you can let down a bucket into the well, and raising it to the surface, turn it upside down, to let the gas out. This must be done a great many times. If this plan does not remove the gas, a bundle of burning straw may be let down into the well. This will heat the gas and make it rise, while good air will take its place.

You have already learned that there is some carbonic acid gas in the air, mixed with the oxygen and nitrogen. Why is it thus mixed with them? As it is heavier than these gases, why does it not lie all along close to the earth, with these above it, as water lies under the lighter oil when they are in a vessel together? It is because gases are so ready to mingle together. The least motion will make them do it at once, and you know that there is always motion in the air, even when it appears to be still.

But at the bottom of a well or a pit, where the air is not in motion, the gas collects there quietly, just as it did in the bottle when we poured hydrochloric acid on marble.

There are some places on the earth where carbonic acid collects in large quantities. There is such a place in Italy, called the Grotto del Cane, or Dog's Grotto. The reason of this name you will soon see. On the floor of this grotto or cave there is always a layer of this gas. The layer is high enough to reach above the head of a dog, but not the head of a man. A man lives near by who shows the grotto to visitors, and when he enters he takes his dog in, who, of course, falls down senseless. He brings him out, however, quickly into the fresh air, which, with a dash of cold water, revives the dog, so that the same thing can be shown to the next visitors. Rather cruel sport; but visitors to the cave almost always want to see the experiment. The gas in the grotto comes out of the crevices in the rocks, and it collects on the floor of the cave, because the air is so shut in that the wind can not reach it.

When wood or charcoal burns, this same carbonic acid gas is formed; if charcoal is burned in an open furnace, in a close room, with all the doors and windows shut, the gas collects and makes the air very bad to breathe, sometimes poisoning persons. The remedy is very simple: you should open the doors and windows, to let fresh air in and the poisonous gas out.

There is considerable carbonic acid gas in beer, champagne, bottled cider, etc. It is that which bubbles up and makes the foam when the cork is drawn. Where is it before we draw the cork? If you hold the bottle up to the light, you see nothing there but the liquid. But the gas is all there. Its particles are all crowded in and concealed among the particles of the liquid. The gas is imprisoned, as we may say. But when we draw the cork, it is set at liberty, and, as it comes out eagerly and quickly to the air, it carries up some of the liquid with it, making a froth. In what is commonly called soda-water there is no soda, but it is water into which carbonic acid gas has been forced by machinery.

We sometimes, however, make soda-water with two white powders: we dissolve one in some water in one tumbler, and the other in water in another; pouring them together, the gas bubbles up and makes a froth. One of the white powders is a carbonate of soda—that is, soda and carbonic acid; the other powder is tartaric acid; and when the two are mixed, the tartaric acid drives out the carbonic acid, which goes off as a gas.

When we drink soda-water we take some of this gas into our stomach; but although the gas is poisonous to our lungs, it not only does no harm in the stomach, but is refreshing, and does us good.

Questions.—What is said of the formation of carbonic acid gas? What is marble made of? How can the carbonic acid be separated from the marble? Will things burn in this gas? Why not? Can animals live in it? Show how we prove that the gas is heavier than air. Explain what sometimes kills persons in a well. How can the gas in the well be got rid of? What is said of gases mingling? What happens in the Dog's Grotto? What is said of close rooms? How do you explain the frothing of beer and soda-water? Explain the making of soda-water with two powders. Is carbonic acid healthy to breathe and to drink?

CHAPTER VII.

THE AIR WE BREATHE.

You have already learned that the air is a mixture of about four parts of nitrogen gas with one part of oxygen and a small amount of carbonic acid gas. Now, although there is such a very small proportion of the carbonic acid, as shown in the figure on page 29, yet there is really a great quantity of this gas in the whole of the air, for you must remember that the atmosphere is 45 or 50 miles high. It is calculated that over every acre of land there are seven tons of carbonic acid gas.

There are continual additions made to the carbonic acid in the air in various ways. Every fire or light that burns adds to it; for the burning of carbon in wood and other substances unites with the oxygen of the air, and forms carbonic acid gas, which flies off.

Fires and lights lessen the oxygen of the air at the same time that they add to the carbonic acid. If you put a candle under a glass jar with its open end downward, it will burn brightly at first, because there is enough oxygen in the air inclosed in the jar; but soon it will burn dimly, and, after a while, go out. The reason is that the carbon of the candle uses up the oxygen by uniting with it to form carbonic acid. If, just as the candle is about to go out, you lift up the jar, the flame of the candle will brighten up again, because you let out some of the carbonic acid, and the fresh air that comes in supplies the candle with oxygen.

Then, too, every animal is breathing out carbonic acid from its lungs. This you can prove in your own case by a simple experiment. Put some lime into a bottle, fill the bottle with water, shake the contents, and let stand until well settled. Pour off the clear water, which now contains lime in solution, and keep it in another bottle for the experiment. Pour some of this lime-water into a glass, and breathe through a tube into the water; you will find, after a little time, that the lime-water has become quite milky. The reason is that the carbonic acid which came out from your lungs has united with the lime of the lime-water, and formed carbonate of lime, or chalk. After standing a little while, the water will become clear, the chalk having settled at the bottom in a fine powder.

The quantity of carbonic acid which we breathe out in twenty-four hours is considerable. It is calculated that a full-grown man breathes out in twenty-four hours over two pounds of carbonic acid, which is equivalent to half a pound of solid carbon, or charcoal. He throws off, therefore, from his lungs, in the course of a year, nearly 200 pounds of charcoal — considerably more than his weight, even if he be quite a large man.

As all animals, of every size, from the elephant down to the smallest insect, are constantly breathing out carbonic acid gas, the supply of this gas from this source must be very great.

All animals also take in oxygen from the air with every breath. It goes into their blood, and becomes a part of it.

Your blood would not keep you alive if it did not constantly take up oxygen as it runs through the lungs.

See now how the air which you breathe out differs from that which you breathe in. That which you breathe out has less oxygen and more carbonic acid. The nitrogen is not altered. Just as much of this comes out as goes in.

If people are shut up in close rooms, the carbonic acid accumulates very fast; and after a while, unless fresh air be let in, they will suffer dreadfully for want of oxygen, and may even die.

We will tell you the story of an emigrant ship called the *Londonderry*, which illustrates this. The ship was crowded with poor emigrants, and many of them were on deck. A terrible storm arose, and the captain ordered them all to go below into the cabin. There they were very much crowded, and fresh air came to them only through an opening in the deck; and since the sea-water dashed down through this in great quantities when the waves broke over the vessel, the captain ordered that tarpaulin (cloth through which neither water nor air can pass) should be nailed over it. The people below immediately suffered dreadfully for want of fresh air, and they cried out in their distress, but the noise of the storm prevented their being heard. At length one of the emigrants succeeded in forcing a hole through the tarpaulin. He told the captain that the people were dying for want of air. The tarpaulin was pulled up at once. Many were already dead, and many were just about to die.

All animals, then, in their breathing, and all fires and lights in their burning, add to the carbonic acid in the air and lessen the oxygen. What is there, then, to hinder the air from becoming all the time more and more laden with carbonic acid, and less and less supplied with oxygen? Just here comes in a wonderful and beautiful provision of the Creator. He has provided the means of taking away carbonic acid constantly from the air, and of supplying it all the time with fresh oxygen. And what, think you, are the agents that God has appointed to do this work? The leaves. They, too, breathe; but their breathing is different from that of lungs. While lungs, in their breathing, give out carbonic acid, leaves take it in; and while lungs take in oxygen, leaves give it out. Every leaf that you see gleaming in the sun is busy pouring out into the air oxygen from all its little pores, and taking in, at the same time, carbonic acid gas. The carbonic acid which the leaves absorb furnishes carbon for the growth of the plant.

There is, therefore, a regular exchange going on between leaves and lungs everywhere; lungs give carbon to leaves, and take back oxygen in exchange.

Questions.—What are the gases in the air? What is said of the quantity of carbonic acid in the air? What effect have fires and lights upon the air? How does a candle burning under a glass jar illustrate this? How does the breathing of animals affect the carbonic acid of the air? Give the experiment with lime-water. What is said of the quantity of carbon thrown off from the lungs? What of the supply of carbonic acid to the air from the lungs of all animals? What is said of the taking-in of oxygen by the lungs? Tell the story of the emigrant ship. What is said of the breathing of the leaves? What is said of the exchange between lungs and leaves?

CHAPTER VIII.

HYDROGEN. THE WATER WE DRINK.

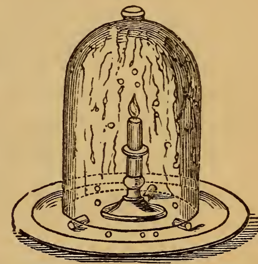
Water is composed of two gases. One of these is oxygen, of which you have learned so much in previous chapters; the other is hydrogen. This is the lightest of all gases, and therefore the lightest of all substances. Air is nearly fifteen times as heavy as hydrogen. A balloon, therefore, filled with this gas goes up very swiftly in the air.

Hydrogen burns with a pale-yellowish flame, giving out much heat, and but little light. How strange it seems that oxygen, which makes other things burn, and hydrogen, a gas which itself burns, combine to form a liquid that puts out fire!

What will seem stranger still to you is that when hydrogen gas is burned in oxygen, water is formed. In the burning, the oxygen and the hydrogen unite. Not a particle of either of them is lost. They merely go into a new condition, uniting to form a liquid. In doing this, the bulk of both of them is made much smaller. It takes a great deal of these gases to form a very small amount of water.

When hydrogen burns in air, we have the same result as when it is burned in oxygen. The hydrogen unites with the oxygen of the air, and forms water. It will have nothing to do with the nitrogen in the air, but lets it alone, and takes the oxygen and combines with it. Several experiments prove that

Fig. 13.

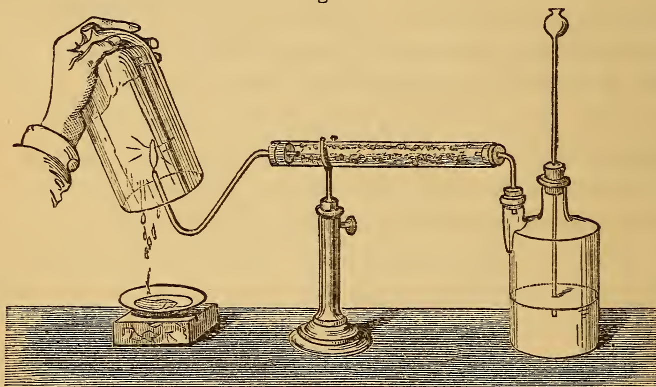


water is formed by the burning of hydrogen in air. In Fig. 13 you see a candle placed on a plate under a glass jar, the jar being supported by three bits of wood. Water flies off from the flame, and collects on the inside of the glass jar. But what has this experiment to do with hydrogen? you ask. We will explain it. The tallow of the candle is made up of carbon and hydrogen combined. Yes, this lightest of all the gases helps, in this case, to form a solid substance. As the melted tallow goes up the wick, the air brings oxygen to it, and the heat makes this oxygen unite with both the carbon and hydrogen of the tallow. By uniting with the carbon it forms carbonic acid. This is, you know, a colorless transparent gas, and so you do not see it. But there it is in the jar. Uniting with the hydrogen, the oxygen forms water, and this goes up in vapor with the carbonic acid. But this vapor soon condenses on the inside of the glass, because it is cool. The glass therefore becomes dim, and after a little time enough water collects to form drops and trickle down into the plate.

Fig. 14, on the next page, represents another experiment. Here hydrogen alone is burned without carbon. The bottle contains the materials for making the gas, of which we will soon tell you. The gas is dried by passing through the large tube, and then comes out of the end of the smaller tube, where it is lighted and burns. Now, if you should let the hydrogen quietly burn without holding any cold glass over the flame, you would not see any water; but, just as in the last experiment, water collects on the side of the glass jar placed over the flame, and trickles down into the saucer beneath. The hydrogen combines with the oxygen of the air, forming vapor of water, and this condenses into liquid drops.

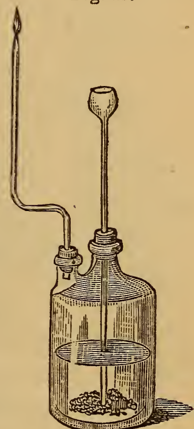
We will now tell you how hydrogen is obtained. Put into a bottle some bits of zinc, some water, and a little sulphuric

Fig. 14.



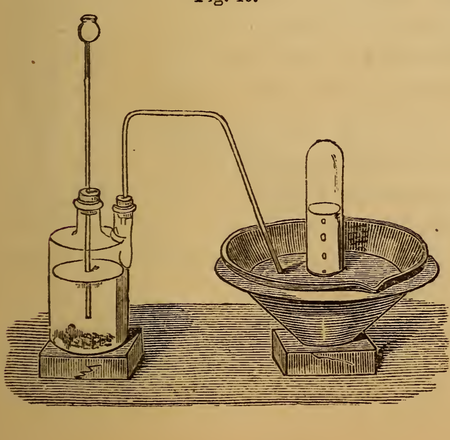
acid, which is sometimes called oil of vitriol. Now, the oxygen of the water unites with the zinc, and this dissolves in the acid, while the hydrogen of the water is set free. This rises and passes out of the vessel, carrying the air that is in the vessel along with it; and soon, when all the air is driven out, the gas comes out alone. In Fig. 15, on the top of the following page, is represented what is called the philosopher's candle. The zinc, water, and sulphuric acid are in the two-necked bottle, which is fitted with corks having tubes in them. Acid and water are poured into the bottle through the tube ending in a funnel, and the gas comes out of the bent tube. The gas issuing from the tube burns just as illuminating gas does when it issues from a gas-burner. Much caution is required in burning the gas made in this way, for a mixture of it with common air is explosive. If, therefore, you should hold a light to the tube before the air is driven out, you might have an explosion, and your bottle might be broken, and its contents scattered about.

Fig. 15.



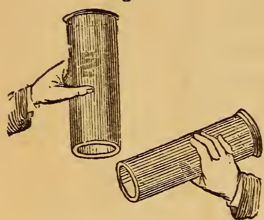
In order to collect a considerable quantity of this gas, chemists generally make use of another sort of apparatus, shown in Fig. 16. The materials are placed in the bottle, as before, and the gas passes through the bent tube into the bowl of water, and thence up into the glass cylinder, forcing the water down just as was explained in the preparation of oxygen (see Fig. 3). In this way several jars may be filled with the gas; and so long as the mouths are kept under water, the hydrogen can not fly away.

Fig. 16.



You remember what was said about pouring carbonic acid gas downward. You can not do this with hydrogen. It is so light that, the moment it escapes from a vessel, it passes directly and quickly upward. You can let a jar of carbonic acid gas stand, and the gas will not go out; but if you set down a jar of hydrogen gas with its mouth upward, the gas will at once pass out, the air coming in to take its place. If you want to pour hydrogen gas from one jar into another, you must hold them in the manner represented in Fig. 17, the upper jar being the one which is to receive the gas.

Fig. 17.



If you set fire to the hydrogen in a jar, it burns differently according to the way in which you hold the jar. If you hold it with the mouth upward, the gas, rapidly rising, bursts upward with a large flame, as seen in Fig. 18. But if you hold it with the mouth downward, the gas burns very quietly as it issues slowly from the mouth, as shown in Fig. 19. Here the gas does not come out freely, for its lightness prevents its coming *down* out of the jar.

Fig. 18.

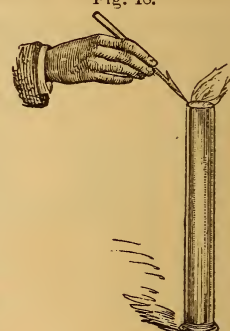
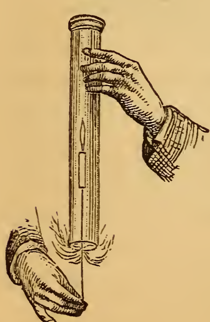
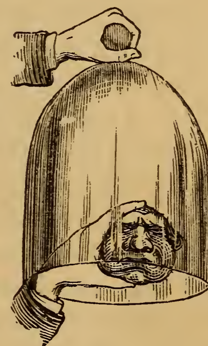


Fig. 19.



As hydrogen is so light and thin a gas, it has a very curious effect upon sounds. If a squeaking toy is made to utter its voice in a jar of hydrogen, as represented in Fig. 20, the sound is very ludicrous.

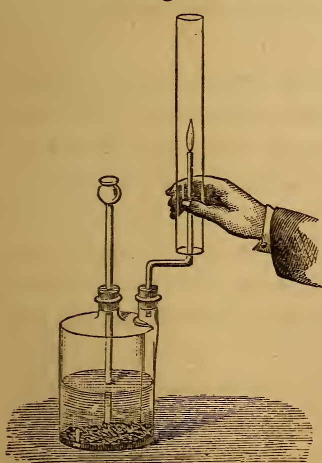
Fig. 20.



Musical sounds can be made by burning this gas in glass tubes, as represented in Fig. 21. These sounds vary according to the sizes of the tubes. They vary also as you raise or lower the tube. Great amusement can be afforded by the variety of sounds thus produced.

Burning hydrogen gives but a faint light; but the light of the gas that we burn in our houses is very bright, and yet it is partly hydrogen. The reason that it gives so bright a light is that carbon, or charcoal, is united with the hydrogen (and on this account it is called by the chemist *carbureted* hydrogen). Watch the flame from a gas-burner, and you will see little bright points all the time sparkling upward. These are occasioned by the burning of the minute particles of the carbon.

Fig. 21.



In the burning of illuminating gas, the oxygen of the air, as in the case of the candle, unites with both the carbon and the hydrogen, forming, with the carbon, carbonic acid gas, and with the hydrogen, water.

And if you hold a glass jar over the burner, the watery vapor will condense on the inside of the jar, as in the similar experiment with the candle.

When illuminating gas escapes without burning, it has, you know, a very disagreeable odor; but when it is burned, you do not smell it at all. Why? Because it is consumed by the oxygen of the air in forming water and carbonic acid, and neither of the things formed has any smell. The smell of the gas is useful to warn us of danger. If it had no odor, whenever there is a leak of gas we would not know it, and might take a light into some place where there is a great deal of it. An explosion would be the consequence, and great harm would be done, and perhaps lives would be lost. Since, however, we can smell the gas, when it has been leaking we open all the doors and windows, and let them remain open for some time before we go in with a light.

The interesting gas hydrogen is never found free in nature, but is always combined with some other substance. It is contained in wood, oils, fats, coal gas, and soft coal; but by far the greatest amount of hydrogen occurs, combined with oxygen, in water. Have you ever thought how abundant water is? "It covers three-quarters of the earth's surface, in the form of ocean, lake, and river; and in the higher latitudes, snow, ice, glacier, and iceberg. Rising in the form of vapor, it produces, by condensation, clouds, fog, mist, rain, and snow. In the vegetable kingdom it is ever present, varying in quantity from ninety-nine per cent. down to fifteen or twenty. Dry wood contains twenty per cent. of moisture. Animals consist largely of water; an average man weighing 150 pounds contains about 116 pounds of water. The rocks contain it; some hold it in large quantity. Gypsum contains twenty per cent. of water, and even hard rocks like granite contain a fraction of a per cent."—C. F. Chandler.

The water we drink is not pure oxygen and hydrogen. Owing to the power it possesses of dissolving minerals, spring-water and river-water contain small quantities of common salt, limestone, gypsum, and other substances dissolved in them. These, together with organic matter resulting from the decay of vegetable or animal substances, constitute the impurities of drinking-water. In some portions of the country, where the water runs over limestone rocks, much lime is taken up by the water, which is then said to be *hard*. Other impurities of water are mud, clay, and even fine particles of sand.

Pure water is obtained in several ways; one of the simplest is by filtration: the water is poured into an apparatus containing some porous material, such as charcoal, which separates many of the impurities as the water trickles over it. Water may also be purified by boiling it, particularly if its impurities are of animal and vegetable origin, these being especially injurious. Water is best freed from these various impurities by distillation, an operation in which the water is converted by heat into steam in one vessel, and this steam is cooled down again to liquid water in another vessel. This plan is used on shipboard: sea-water being distilled is rendered fit for drinking. The water obtained by cooling the steam is called *distilled water*.

When the amount of the mineral substances is large, or the ingredients are rather uncommon, the waters have a saline or peculiar taste, and are called mineral waters. Such waters may be valuable for their medicinal properties, or as sources of the special substances they contain. The mineral waters of Saratoga, New York, and the various hot and mineral springs of Virginia, California, and Ohio, as well as of different parts of Europe, are examples of medicinal waters. Some of these waters contain a gas dissolved in them, which bubbles up continually, and makes the water very pleasant to drink. This gas is carbonic acid, about which you learned in Chapter VI. We will speak of sea-water later; meanwhile, let me remind you what we stated at the beginning of this chapter, viz., that water is composed of two gases—oxygen and hydrogen.

Questions.—Of what is water composed? What is said of the lightness of hydrogen? What is formed when hydrogen is burned in oxygen? What is said of burning hydrogen in air? What two things are formed when a candle burns? How can we obtain hydrogen? Describe the philosopher's candle. State the contrast between hydrogen and carbonic acid. Tell about the squeaking toy. What is said of burning hydrogen in glass tubes? Why does hydrogen burn with a pale flame and illuminating gas with a bright one? What are formed in the burning of illuminating gas, and how? Why does the smell of this gas disappear in burning? How is this smell useful? What is said of the abundance of water? What of the water we drink? In what ways may water be purified? What is distilled water? What are mineral waters? Name some of the localities in which they occur. What gas makes mineral waters pleasant to drink?

CHAPTER IX.

COMBUSTION.

You have already learned considerable about burning, or combustion, but we will now study the subject more closely.

What we usually call combustion attends the union of oxygen with some other substances, either solid or gaseous, as with carbon and hydrogen. Thus, in the combustion of charcoal, the oxygen unites with the charcoal; when hydrogen burns, oxygen unites with the hydrogen; and when iron burns, as in a jar of oxygen gas, oxygen unites with the iron.

But we commonly use the term combustion only when it is accompanied with heat and light, and yet the union of oxygen with other things often takes place without producing any light. This is when the union takes place slowly. Thus, when iron rusts, the oxygen of the air unites with it, but so slowly that no light is given out; there is heat, but so little of it that it can not be felt, because the union is so slow. It is a very slow fire. Now, this same union takes place when iron or steel burns in oxygen, and then we have both heat and light, because the union is so quickly effected. It is really a combustion in both cases, and the only difference lies in the time consumed. When a man, then, paints his iron fence to keep it from rusting, he really keeps it from getting burned.

You can understand now how water puts out fire. It shuts out the oxygen of the air from the burning substance. It acts much as the paint acts on the iron. But perhaps you will say that there is a plenty of oxygen in water, since it is composed of oxygen and hydrogen, and throwing water on fire is therefore giving it oxygen. This is not so. Oxygen is not in water simply as oxygen; it has formed a *new* substance with hydrogen, and the hydrogen in this new substance holds on to the oxygen, so that the fire can not get a particle of it.

But this is not all. Water operates in another way in putting out fire. It takes from the burning substance the heat needed to keep it afire. This heat is spent in turning the water into vapor or steam.

When you put out a fire by smothering, as it is said, you shut out the oxygen of the air, and the burning stops merely for the want of oxygen. So, if a person's clothes take fire, you need not wait to get water, but wrap the person at once with whatever is at hand—a coat, a rug, or any thing else—thus shutting out the oxygen of the air. An extinguisher put over a candle puts out the light by keeping oxygen from coming to it.

But perhaps you will say that people who burn wood cover up fire to keep it, and why does not the shutting-out of the oxygen of the air put out the fire in this case? Simply because all of the air is not shut out; if it were, the fire would not keep. The keeping of the fire depends on letting in some air through the ashes, so that there may be a *slow* burning.

As fire, or combustion, results from the union of oxygen with the burning substance, the more freely you bring the oxygen to it, the brighter will be the fire. When you blow a fire with bellows to make it burn, you increase the supply of oxygen, and feed it to the fire faster than it would come without the blowing. The coals, perhaps, are just kept alive, as we say, by the little oxygen that is in the still air about them. You blow them, and you bring a great deal more air, and therefore of oxygen, to them, and they brighten up at once. If you could blow nitrogen alone, or carbonic acid gas, upon them, it would put them out, for this would keep away from them the oxygen of the air.

A lighted candle is kept burning by the oxygen of the air, and the more oxygen, therefore, that you bring to it, the more brightly it should burn. Why, then, do you blow a candle to put it out? A boy once supposed that he had given a sufficient explanation in saying that the breath knocks the flame right over. The true explanation is this: A certain amount of heat is needed to keep up the burning. Now, the air may be thrown so rapidly against the candle as to carry off enough heat to stop the combustion; it carries off heat in the same manner that air cools your face when blown against it by a fan. In blowing a fire just starting, we have to be a little careful, or we may blow away too much heat from the fire.

There are some contrivances for making our lights burn very brightly. Their object is to supply oxygen rapidly, but at the same time steadily, and not by sudden blasts. One of these contrivances is a glass chimney. See how this operates. The hot gas and vapor that come up from the light are confined in the chimney instead of spreading out in the air around; they pass up, therefore, very rapidly through the chimney, and so make a strong draught.* This makes the air come rapidly to the light from below, and of course a great deal of oxygen comes to it in a little time.

You see how great the draught is if you hold your hand over the top of the chimney; you will feel a current of hot gas and vapor striking it. You must be careful not to put your hand too near. The whole of this current does not go straight up, but it spreads out as soon as it escapes from the chimney, so that, at a little distance, your hand feels only a small part of the current, and that is somewhat cooled.

Another contrivance is to use a flat wick instead of a round one. You see that such a wick presents a larger surface to the air than a round one, and therefore more of it can be reached by the oxygen.

Some wicks are made annular, the air being admitted on the inside as well as the outside of the circle. A very bright light is obtained in this way.

Observe now how we start a fire. We usually do it by applying something burning to the combustible substance. Thus we set fire to wood by burning paper or shavings. In like manner, when we open a gas-burner, we put to it a burning match, and thus set fire to the stream of gas as it comes out. But think a moment what sets fire to the match. It is by rubbing it, you will say. But how? The friction creates heat enough to cause the oxygen to unite with the phosphorus, and the union is quick enough to make light as well as heat. Thus you see heat

* The manner in which this draught is produced is explained fully in the chapters on Heated Air and Chimneys, in the Third Part of the Child's Book of Nature.

and chemical action cause what we call fire. This is very often seen in kindling a wood fire. Suppose you have a bed of coals beneath the wood, how is the wood set on fire? The coals heat the wood, and, after a little time, they make the wood hot enough to ignite.

Some substances ignite at a lower temperature than others; the degree of inflammability is determined by the attraction of the substance for oxygen. Phosphorus, having a very great attraction for oxygen, takes fire very easily, and requires great care in handling.

Some substances can not be burned at all. Gold is one of them. Iron, you have seen, can be burned—that is, it can be made to unite with oxygen; but you may expose gold to the hottest fire, and it will only melt; it will not burn. It will not unite with the oxygen. And what is true of these two metals in regard to quick combustion, is also true of them in regard to the slow combustion mentioned in the first part of this chapter. Gold never rusts in the air—that is, it is not consumed with a slow fire.

Questions.—What usually occurs in combustion? Illustrate the difference between quick and slow combustion. How does water put out fire? Why does not the oxygen in the water make the fire burn? What is said of putting out fires by other means? Explain the effect of blowing a fire with bellows. What would be the effect if you should blow nitrogen or carbonic acid upon a fire? Explain the operation of a glass chimney on a lamp. If you hold your hand over the top of the chimney, what strikes against it? What is the advantage of a flat wick? What of an annular one? When we set fire to any thing, what starts the fire? Give the illustration of the match; also of the wood set on fire by coals. What is said about the attraction of phosphorus for oxygen? What about the attraction of gold for oxygen?

CHAPTER X.

GAS-MAKING AND GAS-BURNING.

Every candle or lamp is a gas factory.

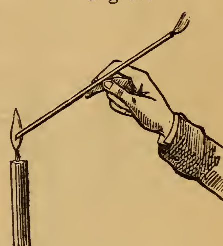
We have told you that both carbon and hydrogen occur in tallow. They are united there as a solid compound; but, when the candle burns, this solid becomes liquefied by the heat at the foot of the exposed part of the wick. See what a cup of melted tallow we have there. It is curious to observe how this cup is formed, and kept just so, all the time the candle is burning. The heat of the burning wick melts the tallow, but that which is nearest the wick is, of course, melted first. This keeps a raised edge all around. If the wick gets bent over to one side, it is apt to melt this edge on that side, and so some of the melted tallow runs out of the cup and down the side of the candle.

But the melted tallow at the foot of the wick must go up the wick to be burned. How is this effected? It rises because there is an attraction between the fibres of the wick and the liquid. This kind of attraction is commonly called *capillary* attraction, because it was first observed on putting the ends of very small tubes into water, or almost any liquid. The smaller the tube, the higher the liquid ascends in it. The small tubes are called capillary tubes, because their bores are as fine as hairs, *capillus* being the Latin word for hair.

The liquid tallow, when it comes to the lower part of the flame, is changed by the heat into a gas, and the burning of this gas makes the flame. What is this gas? It is a compound of hydrogen and carbon. It is much the same gas as that which comes out of a gas-burner.

The flame of a candle is a curious thing to examine. It is not really all flame; a part of it is gas, which is not burning. If you look carefully at the flame when the air is still, you will see that it is hollow, like a shell. Now, the space inside of this shell is filled with gas not yet afire; this looks dark, as you see it through the bright shell of flame.

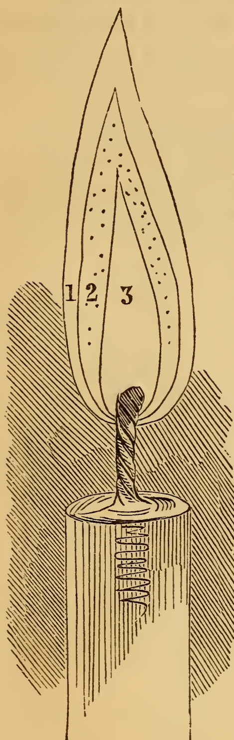
Fig. 22.



You can prove that this dark inner part is gas by some very pretty experiments. Take a small glass tube, and put one end of it, as shown in Fig. 22, in the very middle of the flame—in the dark part. Some of the unburned gas will pass off through the pipe, and you can set it on fire as it issues at the other end. Every candle, then, is a gas factory, and you can take the gas from it in pipes, as we do from the large gas factories that supply towns and cities.

There are really three parts to a flame, as shown in Fig. 23, on the following page, the burning shell being composed of two parts. The outer part of the shell, 1, is not so bright as the inner part, 2. As the gas, 3, rises from the melted tallow, some of it continually passes into the shell, 2, where the hydrogen burns very briskly, and sets on fire the fine particles of carbon. These particles, thus lighted and beginning

Fig. 23.

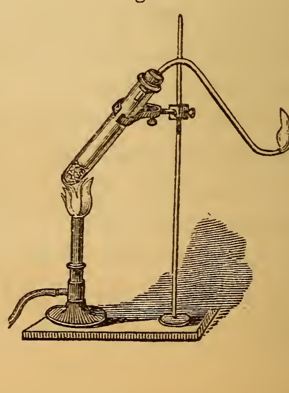


to burn, make that part of the flame bright. As they pass into the outer part of the flame, 1, their burning is finished by a perfect union with oxygen, forming carbonic acid.

The brightness of the flame of illuminating gas is due to these same particles of red-hot carbon. Alcohol burns with a pale flame, because it is not very rich in carbon; turpentine, on the other hand, burns with a very smoky flame, because it contains a great deal of carbon.

The illuminating gas burned in our dwellings is usually made from coal. You can make gas for yourself in a very simple way, and the experiment will help you to understand its manufacture on a large scale. Place some shavings in a glass tube closed at one end, and fitted with a cork and a bent glass tube, as shown in Fig. 24. Then heat the shavings, and soon illuminating gas will pass out through the tube, and you can light it. In place of shavings, you might use soft coal, and then you would imitate the

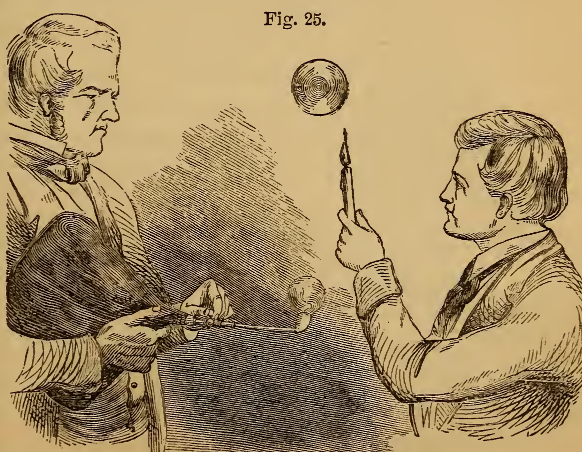
Fig. 24.



method of making gas in large gas-works. Large iron vessels, or retorts, are used, inclosed in furnaces. Into these retorts coal is put, and the heat drives off the gas. It is impure as it comes off, and must, therefore, be purified before it is sent through the distributing pipes.

We have spoken now and then of explosions taking place with gases. Now, what is such an explosion? What takes place? It is a sudden burning of a quantity of gas at once, and the gas, in burning, unites with oxygen. Thus, if we mix oxygen and hydrogen, and then set fire to the mixture, there is an explosion. The whole of the hydrogen burns at once in the oxygen, water forming, just as when hydrogen quietly burns at the end of a tube. When coal gas, escaping from a leak, explodes on bringing a light to it, the explosion is produced by the sudden union of the gas with the oxygen of the air.

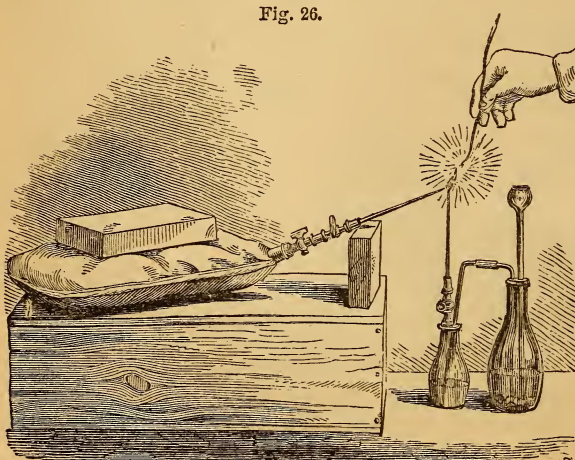
Fig. 25.



You can explode mixtures of oxygen and hydrogen safely in many ways: a neat way is shown in Fig. 25. The man holds an air-tight bag filled with the mixture of oxygen and hydrogen above spoken of, and a tobacco-pipe is connected with the mouth of the bag. In this mouth is a stop-cock, so he can let out the gas as he pleases. By placing the bowl of the pipe in some soap-and-water, he lets out some of the gas, and so forms a bubble. Now, since hydrogen is so very light, and two-thirds of the gas in the bubble is hydrogen, the bubble flies upward. As it flies, the young man touches it with a light, and it explodes. In trying this experiment, caution is necessary, lest the light be brought near the bowl of the pipe, and thus explode all the gas in the bag.

If we let a small stream of oxygen gas and another of hydrogen burn together, a most intense heat is produced. It will melt and burn up the hardest substances. Fig. 26 represents an arrangement for burning these two gases together. The oxygen is in the bag, with a weight upon it to make the gas pass out through the pipe. The end of the pipe is brought close to the flame of the hydrogen, which comes up from a bottle which you see below. For working on a larger scale, the gases

Fig. 26.



are usually kept in iron cylinders, and a double-tubed safety jet is employed. Such an arrangement is called an oxyhydrogen blow-pipe, and was invented by Dr. Hare, of Philadelphia, about seventy-five years ago.

If you hold with a pair of pincers a piece of very small copper wire in the burning jet of these two gases, it will burn with a beautiful green flame. If you use iron wire, bright sparks will fly prettily. The oxygen unites, in this intense heat, with the hydrogen to form water, and with the metals to form bodies called *oxides*. They are called oxides because they contain oxygen. Iron rust is *oxide of iron*, and lime is the oxide of another metal of which you will learn more hereafter.

The Drummond light, of which you have perhaps heard, is made by causing the burning gases, hydrogen and oxygen, to strike against a piece of lime. The lime becomes intensely heated—in fact, white-hot; and shines with a dazzling brilliancy resembling that of the sun. The light receives its name from its discoverer, Lieutenant Drummond, of the English navy. It is used to illuminate buildings at night; in theatres, and in other places where a brilliant light is required.

Questions.—What two substances are in tallow? Describe the melting of the tallow as the candle burns. Why does the melted tallow go up the wick? What is the gas made from the melted tallow? Describe the flame of the candle. How can you prove that the dark inner part of the flame is gas which is not yet on fire? What is said of illuminating gas? Describe the making of gas as represented in Fig. 24. Describe the making of it at the gas-works. What is said of explosions of gases? Describe the experiment represented in Fig. 25. Describe the arrangement in Fig. 26. Tell about the burning of copper and iron in the flame of hydrogen and oxygen. What is the substance formed in burning iron? What is the Drummond light?

CHAPTER XI.

STRIKING FIRE.

Every body has seen fire struck from the heel as it hits upon a stone, and yet how few know exactly what is done! They see the spark, and are satisfied with saying that it is striking fire.

But what is the spark? It is something more than a mere show of light; it is a burning substance. What is this substance? It is a bit of steel or iron from a nail in the heel; this is knocked off as the heel strikes the stone, and there is heat enough made by the blow to set it on fire.

The spark, then, is a particle of burning iron. But how does it burn? Precisely as the steel burned in the jar of oxygen gas. There is oxygen in the air, and the blow of the heel upon the stone makes the bit of iron so hot as to cause the oxygen of the air to unite with it at once; and they unite so quickly that they light up, and so the little mite of iron flies off a bright spark.

The spark falls and goes out. It is so small that you can not find it. But what is it? Is it iron? No, for it has been burned. And what is it to burn iron? It is to make oxygen unite with it. The fallen spark, then, is not iron, but iron and oxygen united—that is, an oxide of iron.

Before lucifer-matches were invented, every family was in possession of a tinder-box for the purpose of striking a light. The apparatus consisted of a piece of steel, a flint, some half-burned rags in a tin box, and some matches, which were splinters of wood tipped with a little sulphur. The way in which a light was obtained was this: The flint was struck upon the steel held over the tinder till the tinder was set on fire by a spark from the steel; then, applying a match to the burning tinder, the sulphur on its end took fire. It often was necessary to work some time to get a light in this way, and a person's patience was sorely tried.

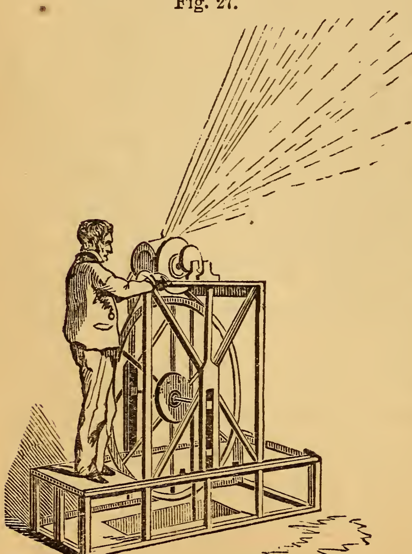
The invention of lucifer-matches, by which we can produce a light in a moment, has caused all the tinder-boxes to be laid aside.

The method which the savage formerly adopted for obtaining fire was more laborious than that of the tinder-box. He sharpened a piece of hard wood to a point, and very rapidly turned this, after the manner of a drill, against a soft piece of wood, having some light chips around it. It required great practice to enable one to move the pointed stick with sufficient rapidity to set fire to the chips. Any one can make two sticks quite warm by rubbing them together, but to make them hot enough to set any thing on fire is a different matter. The Indian, therefore, must have thought the tinder-box a wonderful invention when he first saw the white man use it.

In all these cases the fire is produced in the same way. It is the union of the oxygen of the air with the wood, with the steel of the tinder apparatus, and with the phosphorus of the lucifer-match, that makes the fire; and it is heat in each case that causes the union. The match takes fire the most easily, because but little heat is required to make the phosphorus unite with the oxygen. You can produce enough heat for this by a slight rubbing. It is supposed by some that many of our fires are occasioned by matches carelessly left about: they should always be kept securely shut up in boxes.

What you see on the end of a match is not phosphorus alone, but a mixture of this with some other substances, which make it burn more readily than if it were alone. The reason is, that they have considerable oxygen in them. The more oxygen there is to unite with the phosphorus, the more violently it will burn; and, in lighting the match, the friction makes the phosphorus unite with the oxygen in these substances, in addition to that which is in the air.

Fig. 27.



Machinery is sometimes set on fire by the heat occasioned by friction—that is, the iron part of it becomes so hot that it heats the wood part sufficiently to make the oxygen of the air unite with it. If the axles of railway-cars are not kept well oiled, the heat produced by the friction sets the little oil that is in the axle-boxes on fire—that is, makes the oxygen of the air unite with it.

As the knife-grinder, with

his rapidly revolving wheel or disk of stone, makes sparks fly off, he really burns up a part of the knife he is grinding. In Fig. 27, on the preceding page, is represented a machine for grinding cutlery. A disk of soft iron is made to revolve at the rate of 5000 times a minute. If a hard file be held against the edge of this disk, the rapid friction will burn up that part of the file which touches the disk, and a shower of sparks will be thrown upward. Here you have the same effect produced as when you strike fire with your heel: the union of the oxygen with particles of the file makes the sparks.

Questions.—In striking fire, is the spark merely light? What is it? Give the comparison between this and the burning of iron in a jar of oxygen gas. What is the spark after it has fallen and gone out? What is said of the old-fashioned tinder-box? What is said of the Indian's mode of obtaining fire? What makes the fire in all the cases mentioned? What is said of accidental fires by matches? What of the substance on the ends of matches? What of setting machinery on fire? What of setting oil on fire in axle-boxes? Tell about the knife-grinder.

CHAPTER XII.

ANIMAL HEAT.

What is it that makes your body warm? Clothes and fires, perhaps you will say. No; they help to *keep* you warm, but they do not *make* you so. The heat that makes you warm is produced in your own body, and clothes and fires only serve to keep it in. The heat in you is made by the combustion that is going on everywhere in your body. It is a *real* fire, though there is neither flame nor light.

This is one reason you can not live without oxygen. This gas is needed to keep up the fire in your body, just as it is needed to keep all the fires and lights burning.

The burning in your body is like that of a common candle in the *results* of the combustion. The oxygen of the air unites with the carbon of the tallow-candle to form carbonic acid, and with the hydrogen to form water. So, also, the oxygen that goes into your lungs and enters the blood, unites with the carbon of your body to form carbonic acid, and with its hydrogen to form water.

But in what parts of the body does the oxygen find the carbon and the hydrogen? It finds them everywhere. They make up, in part, the very substances of your body, as they do the substance of the candle. The blood circulates everywhere, to the very ends of your fingers, and it carries in it the oxygen that it takes from the air which comes into your lungs. And the warmth in your fingers, as well as everywhere else, is made by the union of the oxygen with the hydrogen and the carbon present.

But you will ask, "Are carbonic acid gas and water formed in the very ends of my fingers as they are in the burning candle?" Exactly so. "What becomes of them?" you will ask again. "Do they go off from my fingers into the air as they do from the candle?" Perhaps some of the water does. "But the carbonic acid gas, what becomes of that?" It goes in the blood to your lungs, and there is breathed out into the air.

The breathing-out of carbonic acid gas has already been described in Chapter VII. This gas that you breathe out comes, then, from all parts of the body. It is amusing to think that, when you breathe into lime-water and make chalk, a part of the gas you make it with has come from the very ends of your fingers and toes, and has been made there by a sort of fire.

Some of the water, too, formed by this fire in your body goes out in your breath; and it goes out in vapor, just as it goes up from a burning candle. This vapor will collect on a cold glass, if you breathe on it, in the same manner as the vapor from a candle condenses on a glass jar put over it.

The candle burns up; so does your body. The fire is consuming every part of your body all the time. But there is one great difference between your body and the candle in this matter. The candle is soon all gone, for there is no making up for what is consumed. But your body remains about the same day after day, notwithstanding that some of it is burning up all the while. This is because there is in the body a constant supply of new substance in place of that which is burned. Your body, then, is more like a lamp fed by a fountain of oil than like a candle.

A part of the food we eat is fuel to keep up the fire in us—that is, it goes to supply the carbon and hydrogen continually burned up in our bodies. Some kinds of food furnish a great deal of carbon and hydrogen, and so are of great use in keeping up the fire in us. Sugar is one of these; fat is another. Inhabitants of very cold climates—the Esquimaux, for instance—eat large quantities of fat meat and oil, because they are of use in keeping them warm. They need food that has a great deal of charcoal in it for fuel, so that a good fire may be kept up in them to guard against the extreme cold of the climate. They are very fond of this kind of food. A captain of a vessel once invited one of these people to dine with him. His guest declined to take the coffee and wine which were offered him, but, seeing an oil-can near by, he took it up and drank all the oil. That was a drink he had learned to like, for he had been used to drink it to keep himself warm. But the coffee and wine he did not think of much account.

The carbonic acid which a full-grown man breathes out from his lungs in a year contains about 200 pounds of charcoal. Now, all this carbonic acid comes from the fire within his body, and in this fire this large quantity of charcoal unites with oxygen. Where does all this charcoal come from? He swallows it in his food—in the sugar, bread, meat, fat, etc., which he eats. You swallow every year an amount of charcoal which would weigh more than you do, and this is burned up within you to keep you warm.

You know that when you run or play very hard, you become heated. This is because your heart beats more quickly than when you are still, and the blood flows very rapidly in your arteries and veins. At the same time, you breathe quickly. Now, the quick breathing causes more air, and therefore more oxygen, to enter the lungs; more oxygen, of course, gets into the blood, and, as the circulation is quickened, the oxygen is carried everywhere more rapidly; the fire, therefore, burns more briskly in every part of the body.

Did you ever think that your body is always giving out heat to the air around you? The air is almost always cooler than your body, even in very hot weather. You are uncomfortably warm in a hot day, not because the heat of the air goes into your body, but because your body does not give off enough heat to the air. A great many persons, therefore, crowded together give out a great quantity of heat. We often see this illustrated in large parties. The rooms are comfortable at first, when only a few persons are gathered; but when the rooms are crowded, the air is uncomfortably warm.

If you stand out in the cold without sufficient clothing, you become chilled, because the cold air is taking away heat so fast from all the outside of your body.

How can you remedy the difficulty? In two ways. One is to make the fire in you burn more briskly; this you can do by exercising in some way—running, jumping, working. This will make your blood circulate more rapidly, and you will breathe more quickly, so that more oxygen will go into the blood. You have seen workmen in cold weather strike their arms across the body, letting the hands come over upon the back. This is to make the blood go more freely to the very ends of the fingers, that there may be an abundance of oxygen there to unite with the carbon and hydrogen, and so produce sufficient warmth.

Another way to remedy the difficulty is to put on more clothing, which keeps in the heat constantly generated within you. You need more clothing when you are riding in the cold than when you are walking or playing, because the fire is not so brisk when you are still as when you are exercising.

Animals living in cold climates have clothing provided for them by the Creator fitted to keep in the heat which is made in their bodies: they are clothed with furs for this purpose. Contrast the polar bear and the elephant in this respect. The bear has a good furry coat; while the elephant, that lives in a warm climate, has only a few straggling hairs upon his skin.

Questions.—What makes the heat in your body? What is said about not being able to live without oxygen? What does the oxygen that goes into your lungs unite with to produce heat? Where does it go to find the substances with which it unites? How do the water and the carbonic acid formed in the combustion of the body escape into the air? Give the comparison between the candle and your body in relation to the vapor produced by this combustion. What is said of food as fuel? Tell about the Esquimaux. Relate the anecdote of the captain's guest. Explain why you become so much heated on exercising briskly. What is said about our giving out heat to the air? What about many people being together? Why are you chilled when standing in the cold without sufficient clothing? What ways are mentioned of getting rid of the difficulty? What is said about animals living in cold climates?

CHAPTER XIII.

IRON-RUST, POTASH, AND LIME.

Which do you think is the heaviest—a piece of iron, or the same after it is rusted? The iron, you will perhaps say. Why? Because the rust eats it, says one. And, says another, people always say of a stove-pipe, when the rust has made holes in it, that it is rusted away. But let us look at this. When iron rusts, oxygen is added to it or is united with it, and, of course, it will weigh more with this addition. To be sure, oxygen is a very light substance, nearly as light as air, but it has some weight, and this weight is added to the iron when the iron turns to rust; and it is to be remembered that a very considerable bulk of oxygen is added. Whenever you see iron-rust, then, remember that a large quantity of this gas is condensed into a very little space; and being thus united with iron, it is no longer a gas, but a part of a solid substance.

But what we commonly call rust contains something besides oxygen united with the iron: there is water in it. It does not show itself as water, for the rust is dry. How is this? The water in the rust is no longer a liquid, just as the oxygen in it is not a gas. Both the liquid and the gas become parts of the solid substance.

Most metals will, like iron, burn, or, in other words, will unite with oxygen; but there are some metals that will not burn at all. This is because they have no liking or attraction for oxygen. Gold is one. If you apply heat enough to melt it, it will not take any of the oxygen of the air to itself. Hence it is so very useful in gilding articles, for it never tarnishes—that is, never rusts. On the other hand, some metals like oxygen so well that they unite with it at once whenever oxygen touches them, and sometimes burn with violence. Potassium is one of them. This is a metal that has never been found anywhere. How, then, you will ask, do we know that there is such a metal? It was discovered by a celebrated English chemist, Sir Humphry Davy. Davy, by-the-way, was once a poor boy; but he became a great man, because he was always studying and thinking about what he learned.

By means of some very ingenious experiments with potash, a substance with which you are probably familiar, Davy proved that it is not a simple substance, and he obtained from it the metal potassium. He found that potash is composed of oxygen, water, and a metal, in much the same way as iron-rust is made up of oxygen, water, and iron. Potassium, when once obtained, is very difficult to keep, because it is continually uniting with the oxygen of the air; but the air may be shut out by placing the potassium under a liquid called naphtha, and this is commonly done. You understand now why the metal has never been found in the earth by itself, as gold and silver are; it is always combined with some other substance.

Most of the metals you are acquainted with are hard and heavy, but potassium is quite different; it has a bluish-white color, is quite soft, so that you can mold it between the fingers almost like wax when it is a little warm, but it is brittle when cooled down to the freezing-point of water. It is a very light metal, so light that it will swim on water.

If potassium be left exposed to the air, it tarnishes at once, and in a short time is all turned to potash, the oxygen of the air uniting with it.

If you throw a little piece of it upon water, it steals away the oxygen from the hydrogen of the water, and flies about the surface, burning with a beautiful violet flame, as represented in Fig. 28. This flame is the hydrogen set free by the union of the potassium with the oxygen of the water. The hydrogen burns because this union is made quickly, and so produces heat enough to set fire to the hydrogen. The color is given to the flame by the potassium. If this metal be thrown upon ice, the same burning will occur.

Fig. 28.

It seems very strange to us that a metal should float on water, and burn up while it is floating. When Sir Humphry Davy made the discovery, he astonished every body. Even his brother-chemists were astonished. It is related that Davy put a small piece of the newly-discovered metal into the hand of his friend Dr. Wollaston, a celebrated chemist, and Dr. Wollaston spoke of it as being quite heavy. Davy soon showed him his mistake by throwing it into water. The philosopher expected to see it sink like lead, and was utterly surprised to see it both float and burn.

There are several other metals which float and burn on water, but we will only describe one of them, called sodium. Sodium is made from soda, much as potassium is obtained from potash, and it was also discovered by Sir Humphry Davy, about seventy years ago. Sodium, when thrown upon water, decomposes it, taking the oxygen from the hydrogen, as potassium does. A hissing sound is produced, but the escaping hydrogen will not burn unless the water be hot. When it does burn, the flame has a beautiful yellow color, given to it by the metal.

There are great quantities of this metal in the world, for it is one of the ingredients of common salt. Like potassium, it is never found alone, but is always united with oxygen or some other substance.

Lime was supposed to be a simple substance or element before the discoveries of Sir Humphry Davy. But this, like soda and potash, he found to be a compound of a metal. This metal, called calcium, is very difficult to obtain, because it has so great an attraction for oxygen. United with oxygen, calcium forms lime, or what is commonly called quicklime. If water be added to lime, it is called slaked lime. Observe that word *slaked.* People sometimes speak of slaking the thirst; so, in the case of lime, there is a thirst, as we may say, for water, and the lime takes to itself a great deal of it. But it will take only a certain amount, and no more.

Lime will become slaked after a while, if it be merely exposed to the air; for it has such an attraction for water, that it will drink in the moisture from the air.

In making mortar, the quicklime is slaked; and so eagerly do the quicklime and water unite, that great commotion and heat are produced, as you have probably often noticed.

We have not yet described an interesting substance commonly known as hartshorn, but called by chemists *ammonia*. It is a gas of a peculiar pungent odor with which you are probably familiar. It is not a simple gas like oxygen, but is made up of two gases, nitrogen and hydrogen. It is contained in a substance called sal ammoniac, from which it is expelled by heating with lime. This gas dissolves in water, forming a very strong solution, which has the same odor as the gas; it is this solution which is commonly called spirits of hartshorn. You will learn by-and-by that flesh and other parts of animals contain hydrogen and nitrogen; when the animal matter decomposes, these unite, and ammonia is formed. It is ammonia which smells so strong in a stable; it also gives to guano its peculiar odor.

The substances potash, soda, and ammonia are called *alkalies*, having certain properties just the opposite of bodies called acids. You learned about nitric acid in Chapter IV., and you will find more about acids in the following chapters. These substances called alkalies combine with acids and form *salts*, as will be explained more fully in Chapter XVII.

Questions.—What is said of iron? What besides oxygen is added to iron in rusting? In what condition is the water which is added? What is said of the union of other metals with oxygen? Tell about the discovery of the metal potassium. Why is it difficult to keep this metal? Why is it never found alone? In what way is it kept? Describe the metal. What happens to it if it be thrown upon water? Give the anecdote about Dr. Wollaston. What is soda? In what substance does sodium exist in abundance in the earth? What is calcium? What is quicklime? What is slaked lime? What is the meaning of the word *slaked?* Of what is ammonia composed? What are its properties? What substances are called alkalies?

CHAPTER XIV.

METALS. IRON.

Iron-rust, you remember, is a compound of iron and oxygen, and is called by chemists *oxide* of iron to indicate its composition. In like manner potash* and soda are called *oxides* of the metals potassium and sodium respectively. Of these metals you learned some facts in the last chapter, and now we will describe some more metals of interest and importance, noticing, at the same time, some of their compounds.

Most of the metals are heavy. One of them, platinum, is the heaviest substance in the world. But some of them, as you saw in the previous chapter, are so light that they will float in water.

All of the metals are solid except mercury. This is a liquid. It is seen in the bulbs of thermometers.

A metal is a simple substance, an element, and not a compound. There are forty-nine of these metallic elements, while there are only fourteen of all the other elements in the world.

Metals as a class of bodies have certain properties which distinguish them from all other substances. In masses they are *opaque;* that is, light will not pass through them. Glass is *transparent*, which means you can see through it; but you can not see through a piece of iron or tin. The gases are transparent, as you learned in Chapter II. Water is also. You can see sub-

* Not the common potash of commerce, which is in reality an impure carbonate.

stances, you know, at the bottom of clear water in a pond or stream; but if you have a cup full of mercury, you can not see any thing in the bottom of the cup.

There are some substances that you can not see through, and yet light shines through them. They are said to be *translucent.* Metals are neither transparent nor translucent. When gold is made into very thin leaf by hammering, it is translucent; but, however thin it may be made, it is never transparent.

Metals have a certain brilliancy which is called the metallic lustre. Some of them can be polished very highly.

Metals can be hammered into very thin leaves, a property which is called *malleability*, and they may be drawn out into fine wires, a property called *ductility.* You must not imagine that all metals possess these properties to an equal degree; gold is much more malleable than copper, and lead is much less ductile than silver, yet these properties belong to the metals taken as a class. If metals could not be hammered into thin sheets or drawn out into wires, they would be much less useful than they now are.

Iron is the most valuable and abundant of all the metals, and it is put to the greatest variety of uses. It is on account of its usefulness that the Creator has provided so much of it for man in every part of the world. Here are a few lines in which some of the many uses to which this metal is put are mentioned:

"Iron vessels cross the ocean,
Iron engines give them motion;
Iron needles northward veering,
Iron tillers vessels steering;

Iron pipe our gas delivers,
Iron bridges span our rivers;
Iron pens are used for writing,
Iron ink our thoughts inditing;

Iron stoves for cooking victuals,
Iron ovens, pots, and kettles;
Iron horses draw our loads,
Iron rails compose our roads;
Iron anchors hold in sands,
Iron bolts, and rods, and bands;
Iron houses, iron walls,
Iron cannon, iron balls;
Iron axes, knives, and chains,
Iron augers, saws, and planes;
Iron compounds in our blood,
Iron particles in food;
Iron lightning-rods on spires,
Iron telegraphic wires;
Iron hammers, nails, and screws,
Iron every thing we use."

You can think of many other uses to which iron is put besides those just mentioned. We think of a few at this moment—pokers; shovels; sinks; watch-springs; plows; hoops for casks, hogsheads, etc.

Iron is never found in the earth in its metallic state, but always combined with oxygen or some other substances, forming *ores*. These ores are of various colors and degrees of hardness; some are bright-red and friable, some are yellow and earthy, others are black and very hard; you would hardly think they looked as if they contained any iron at all, but the chemist extracts iron from them. The ores are mixed with other substances, chiefly with coal and limestone, and heated intensely in tall furnaces. Perhaps you have seen such furnaces in your travels. You could not very well understand the chemistry of the operation, and we will reserve it for the next higher book on chemistry. The iron thus obtained is more or less impure. The very best iron that can be bought has some carbon in it.

There is a great difference between cast-iron and wrought-iron. Cast-iron, you know, is very brittle, while wrought-iron is not. The difference in composition is this: In every hundred pounds of cast-iron there are from three to five pounds of carbon, while there is only from one quarter to one half a pound in every hundred pounds of wrought-iron. But this is not all —the structure is very different in these two kinds of iron. If you observe the broken edge of cast-iron, you will see that the iron is in little grains; the structure, therefore, is said to be *granular*. But wrought-iron seems to be composed of threads or fibres of the metal lying along-side of each other; so it is said to have a *fibrous* structure.

These two kinds of iron are used for different purposes. Pots and kettles are made of cast-iron; but it would not do to have any thing made of this which is to be continually knocked against hard things. If, for example, horseshoes were to be made of cast-iron, they would be broken by the first stone upon which they should strike; they are therefore made of wrought-iron. For the same reason, the nails with which they are fastened to the hoof are made of wrought-iron.

Wrought-iron can be *welded*, but cast-iron can not be. In this welding, which can be done only when the iron is red-hot, the hammering unites the fibres in the two pieces together. You can readily see that this can not be done with the grains of the cast-iron.

Cast-iron is so brittle that it can not be hammered into sheets at all; it is not, then, malleable in any degree. But wrought-iron is considerably so; it is also ductile.

Steel is a kind of iron, or rather a compound of iron and carbon. In every hundred pounds of steel there are from two to two and a half pounds of carbon. In respect to the amount of carbon in it, therefore, it is half-way between cast-iron and wrought-iron. It may be made from either cast or wrought iron. When it is made from cast-iron, it is done by burning out half of the carbon that is in the cast-iron. When it is made from wrought-iron, carbon is added by heating, for several days, the wrought-iron with charcoal in iron boxes.

There are two kinds of steel. One is brittle; the other is just the opposite—it is very flexible. Some swords can be bent double without breaking, and yet will at once become straight again. The difference between the two kinds of steel is made in this way: If steel be heated, and then suddenly cooled, it will be hard and brittle; if it be cooled slowly, it will be soft, and it can be readily hammered out like wrought-iron. All very sharp-cutting instruments are made of hard steel, and therefore are easily broken, as you may have learned some time by carelessly breaking your pocket-knife.

We have spoken of the abundance of iron in the earth. Besides the ores from which iron is obtained, there is also a great deal of iron scattered through other substances. For example, almost all black and green stones get their color from an oxide of iron in them. The yellow stains which we sometimes see in marble and other stones come from an oxide of iron, which, by exposure to the air, has become iron-rust. Iron-rust occurs in all soils, but in some there is a great amount of it, giving them a red or yellowish-brown color.

There is one ore of iron which is often found in the form of beautiful crystals; and as it has a color somewhat like gold, it has often been supposed to be gold by people who do not understand such matters; it is, therefore, called "fools' gold." People sometimes bring samples of this ore to chemists, supposing it to be a precious metal, and expecting to make a fortune, perhaps, from what they may gather from their land. They are very much disappointed to learn that their gold is nothing but iron combined with sulphur, forming a mineral named *pyrites*.

Iron is found in great abundance in various parts of the United States. You have heard, perhaps, of the two iron mountains in the State of Missouri. They are ninety miles south of St. Louis. One of them is three hundred feet high, and the other seven hundred. The ore of which they are mostly composed is an oxide of iron. Every one hundred pounds of the ore contains seventy pounds of iron and thirty of oxygen; but there are some impurities mingled with the ore. These mountains are made up of lumps of all sizes, from that of a pigeon's egg to that of a large house.

Questions.—What is said of the weight of the metals? How does mercury differ from the other metals? How many metals are there? Explain what is meant by metals being opaque, malleable, and ductile. What is said of the uses of iron? In what state is it found? How is it freed from what it is united with? How do wrought-iron and cast-iron differ? What is the structure of wrought-iron? What are the different purposes to which these two kinds of iron are suited? What is said of welding iron? What is steel? How is it made? What are the two kinds of steel? How is the difference between them made? For what different purposes are they used? What is said of the presence of oxides of iron in different substances? What is said of "fools' gold?" Tell about the iron mountains of Missouri.

CHAPTER XV.

MORE ABOUT METALS AND THEIR COMPOUNDS.

Lead is an abundant and very useful metal. Its most common ore is called galena, and is a compound of lead and sulphur. The bright shining crystals and masses of galena look very much like the metal itself; but if you tried experiments with it, you would very soon learn the difference.

Lead mines have been found in many different countries in all quarters of the globe. There are some very extensive ones in this country, especially at the West, in Missouri, Iowa, Illinois, and on the Pacific coast.

Lead has a bluish-gray color, and is not very lustrous unless recently cut; in other words, it *oxidizes* or tarnishes easily. Lead is quite easily hammered into sheets, and it melts at a low temperature. But it is a weak metal, for a lead wire can not hold up much weight.

One of the compounds of lead with oxygen has a fine red color, and is largely used for making red paint.

The uses of lead are extensive and various. Lead pipes, sheet-lead, lead bullets, and lead shot are familiar objects. Lead melted with other metals forms useful mixtures, of which we shall tell you in the latter part of this chapter.

Tin is a bright white metal, very soft and malleable. It does not tarnish easily; that is, it does not readily rust or unite with the oxygen of the air. Tin-ware, therefore, as you know, is easily kept bright. This tin-ware is not all tin. There is really more iron than tin in it. It is sheet-iron coated with tin. In making it, thin sheets of iron are dipped into melted tin.

There are tin mines in various parts of the world. The most famous are those of Cornwall, in England. But little of this metal is found in this country.

Copper is a metal of a red color. It does not tarnish or oxidize so easily as iron, and stands heat very well, so it is used for making vessels for cooking purposes. Copper is quite malleable, so that it is readily made into sheets, such as are used in sheathing the bottoms of ships. It is also very ductile, and the wires made of it are very strong, though less so than iron wires. Copper is found quite pure in the earth: near Lake Superior, Michigan, immense masses are found, some of them weighing thousands of pounds. Copper is also found in many parts of the world combined with sulphur, with oxygen, and other substances, and these compounds form very important ores. The compound with sulphur resembles "fools' gold," but has a deeper yellow color.

Zinc is a bluish-white metal which tarnishes very readily, as is shown by the whitish coating which gathers upon it. Zinc is brittle when cold; but if heated to a particular degree, it can be rolled into sheets. This discovery has made zinc useful for a great variety of purposes. Sheet-zinc is employed for covering roofs, lining refrigerators, sinks, etc., and for protecting the floor or carpet from the heat of stoves, besides various other purposes.

Mercury is the only metal which is a liquid. It is a white metal, having a brilliant metallic lustre. It becomes solid in the extreme cold weather of the arctic regions. Therefore, when Dr. Kane and others went to those regions, they were obliged to use thermometers containing alcohol, which has never been known to become solid.

This metal is sometimes found pure. It is said that the mines in Mexico were first discovered in this way: A hunter, as he was ascending a mountain, caught hold of a shrub to assist him; the shrub gave way at the root, and there ran out from the ground a stream of mercury. It was supposed to be liquid silver, and from its quick movement as it runs along it has received the name of *quicksilver*.

Mercury is also found combined with sulphur, making a very beautiful vermilion-colored mineral called cinnabar. The most famous mines of mercury are in Austria, Spain, and California.

Silver occurs in nature sometimes pure, sometimes in alloys or mixtures with other metals, as copper, and sometimes united with sulphur or some other substance. The most famous mines are in Mexico, Nevada, Saxony, and South America. This metal is very malleable and ductile. It is not so hard as copper, nor so soft as gold.

Gold is rarely found in nature united with other things, as most metals are; it is found either pure, or mixed with some other metals, forming an alloy. It is usually alloyed with silver. It is found in rocks, or in sands that have worn off from rocks by the weather, and been washed down by the rain.

Platinum is a metal having a color like that of steel. It is the heaviest and most infusible of all known substances. Mercury, silver, gold, and platinum have been called the noble metals, because they are never tarnished or oxidized by the oxygen of the air.

When metals are melted together, they mix and form alloys. Alloys are not true chemical compounds, like the oxides and the compounds of the metals with sulphur, to which we have alluded, but are mere mixtures: it is with these alloys much as with the liquids alcohol and water, which may be mingled in any proportion you wish.

Pure water from every pond, river, lake, and ocean in the world always contains the same proportion of these two gases, sixteen of oxygen and two of hydrogen. Now, what is true of water is likewise true of all chemical compounds: we do not mean that the proportions are always two and sixteen, but that bodies combine in *some definite proportion.* Iron-rust contains, for example, in every 214 pounds 112 of iron, 48 of oxygen, and 54 of water; laughing-gas contains in every 44 pounds 28 of nitrogen and 16 of oxygen, etc. When you have studied chemistry longer, and have reached the next book of this series, you will learn more about this subject; meanwhile, observe the great difference between chemical combination and mixtures like alloys.

You may melt together, for example, one pound of lead with one, two, five, ten, or fifty pounds of tin, and the two will mix, and, on cooling, form an alloy, the properties of which vary with the amount of each metal. Now, the case is quite different with bodies which unite chemically, as when carbon and oxygen combine to form carbonic acid, or hydrogen and oxygen combine to form water; in these cases the substances unite in definite proportions, and the compound formed always contains the same amount of each of the bodies contained in it. *Eighteen* pounds of water are known to contain *sixteen* pounds of oxygen and *two* pounds of hydrogen, never more and never less of either; thus, if you had a vessel holding *twenty* pounds of oxygen and a bag of *two* pounds of hydrogen, and should mix them and cause the gases to unite by setting fire to them in a proper apparatus (a dangerous experiment on so large a scale), so that the water formed could be collected and weighed, you would find only *eighteen* pounds of water and *four pounds of oxygen remaining.*

There is another difference between alloys and true chemical compounds. When two substances unite to form a compound, the substance which is formed is not, in its properties, between the two that form it; an entirely new substance is formed, and generally wholly different from either of the substances of which it is composed. But see how it is with alloys. Brass is a mixture or alloy of copper and zinc. Its color is made lighter than copper by the zinc, about one quarter of it being of this metal. The brass is between the two metals in this respect, and also in other properties.

These mixtures of metals are of very great value in the arts. We have just told you that brass is an alloy of copper and zinc, and you know how many things in common use are made of brass. Pewter is another alloy, made of tin, lead, and antimony; the solder used by plumbers is an alloy of tin and lead. Copper and tin melted together in different proportions make bronze or bell-metal, the latter containing more of the tin. German silver, as it is called, contains no silver at all; it is an alloy of copper, zinc, and a metal not yet mentioned, called nickel.

The gold and silver in common use are not pure, but are alloys. This is true both of money and of the articles for use and ornament made of these metals.

When one of the metals entering into the composition of an alloy is mercury, the mixture is called an *amalgam.* One amalgam you are very familiar with, though perhaps you do not know of what it is made; this is the material on the back of looking-glasses. This is an amalgam of mercury and tin. It is put on in this way: Tin-foil, that is, tin-leaf, is first applied all over the glass; then mercury is poured upon this, and it unites with the tin, making an amalgam.

Even gold and mercury unite to form an amalgam. If you should try to pick up some mercury from the carpet after accidentally breaking a thermometer, and should have a gold ring on your finger, you would be very likely to spoil the ring. The gold would turn white by alloying with the mercury, and it would be necessary to heat the ring to redness to drive off the mercury again.

Questions.—What is said of the occurrence and properties of lead? What of its uses? What are the qualities of tin? What is sheet-tin made of? What are the properties of copper? Where is it found? What is said of zinc? What of its uses? What metal is liquid at ordinary temperatures? Relate the anecdote of its discovery. Where is it found? How does silver occur? Where is gold found? What is said of platinum? Name the noble metals. Explain the differences between alloys and chemical compounds. Of what is brass made? Of what pewter? Of what German silver? What is an amalgam? What is said of the material on the back of looking-glasses? Give an illustration proving that gold and mercury form an amalgam.

CHAPTER XVI.

SULPHUR AND PHOSPHORUS.

Sulphur is such a common substance that we have mentioned it several times without explaining what it is. But the chemist has found out many interesting things about sulphur, which we shall now describe.

We see sulphur ordinarily in two forms—roll brimstone and the flowers of sulphur. The flowers of sulphur are obtained by heating the sulphur so as to make it rise in vapor, the vapor being condensed so as to form fine powder. The roll brimstone is obtained by melting the sulphur and letting it run into molds.

Sulphur is very abundant in nature. It is found as sulphur, and sometimes in beautiful yellow crystals, in the neighborhood of volcanoes; but it is most abundant in combination with other substances. You have learned, in the chapters on the metals, that they frequently occur combined with sulphur; such compounds are called *sulphides*, just as the compounds of substances with oxygen are called oxides. Thus the compound of sulphur nicknamed "fools' gold" is called in chemistry sulphide of iron. This mineral is an important source of sulphur. Sulphur also exists in the mineral called gypsum, or plaster of Paris, which is very common; and, besides, sulphur enters into the composition of many vegetables, such as onions, pease, horse-radish, and beans; and of portions of animals, as in the hair, flesh, etc. It is the sulphur in an egg that blackens a silver spoon.

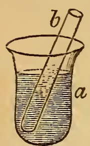
The following is an easy experiment with sulphur: take a glass tube six or eight inches long and closed at one end, and place in it several pieces of roll sulphur the size of a pea. Twist a wire around the mouth of this test-tube, as it is called, and heat the tube in a gas-flame, as shown in Fig. 29. The wire serves as a holder, to prevent burning your fingers. The sulphur melts and sinks into the bottom of the tube; at first it is thin like water, but on heating longer it becomes brown and thick. If you heat it a little more it becomes liquid again, and on pouring this into cold water the sulphur hardens into a waxy mass. In this state the sulphur may be pulled out into strings like India rubber, but after a few days it becomes hard and brittle again.

Fig. 29.

Sulphur burns in the air with a pale-blue flame, giving rise to a gas with a disagreeable, suffocating odor. The next time you light a match, look closely at the bluish flame of the sulphur, and smell the gas cautiously; but perhaps you have been half choked with the gas already. By burning sulphur in a particular way in the presence of nitric acid and steam, and condensing the fumes formed, an oily corrosive liquid is obtained called sulphuric acid. This acid is made on a very large scale, and is of great use for many purposes. When unmixed with water it is very strong, and must be handled with great care; a few drops on your clothes would eat holes through them, and a little on your fingers might burn them badly.

If sulphuric acid and water be mixed, there is produced at once a considerable degree of heat. This may be shown by some very interesting experiments. We shall mention two. One is represented in Fig. 30. In the vessel, *a*, are sulphuric acid and water just poured in. In the test-tube, *b*, is some ether, which boils with much less heat than water does. Stirring this test-tube around in the acid and water, there is enough heat produced in a few moments to make the ether boil. Another experiment is this: Put some tow or cotton around a wine-glass, having some little bits of phosphorus so placed in the tow as to touch the outside of the glass. Pour some water into the glass, and then some sulphuric acid. The heat produced will set fire to the phosphorus, and this in turn will set fire to the tow.

Fig. 30.

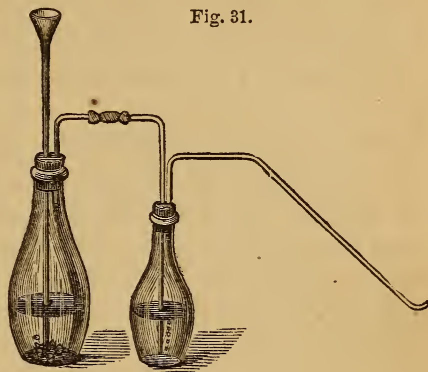


Sulphuric acid absorbs water very eagerly: it will even abstract water from dry wood, as is proved by the following experiment: Pour some strong sulphuric acid into a glass, and dip into it a piece of wood; hold it a moment in the acid, and lift it out, taking care not to drop any acid on the table. You will see that the stick is nearly black, certainly quite brown, owing to the charcoal or carbon contained in wood appearing on the surface.

Sulphur combines with hydrogen, which you remember as a very light, combustible gas, and forms a gas of very disagreeable odor. It smells like spoiled eggs; in fact, the odor of spoiled eggs comes from this gas itself. The coal gas burned in our houses for the purpose of lighting them sometimes contains considerable of this gas, and owes part of its bad odor to its presence.

Perhaps you think we have forgotten to name the gas, but we only put off naming it, because the name is so long that we fear you will be unable to remember it. It is commonly called *sulphureted hydrogen*, since it contains sulphur and hydrogen.

Fig. 31.



The gas may be made by pouring some sulphuric acid, mixed with water, over pieces of sulphide of iron put into a bottle, like that shown in Fig. 31. The gas begins to bubble out of the liquid almost immediately, without heating. The second bottle shown in the engraving contains some water, in which the gas dissolves. After some time the water refuses to dissolve any more gas, and then the gas passes through the curved tube; and if a light be applied at the opening, the gas will catch fire and burn. Perhaps you wonder why we describe the manner of making a gas having such a very offensive odor: it is because many pretty experiments can be made with the solution of the gas in water; and when you are sufficiently advanced to study chemistry in a laboratory, you will need to use this solution almost daily. We told you to use sulphide of iron to make the gas, but we do not mean the mineral called "fools' gold;" this would not answer. An artificial sulphide of iron is used, obtained by melting sulphur and iron together.

We shall now tell you about phosphorus. This substance exists extensively in nature, but never by itself, like sulphur. It is always united with other substances. It is commonly obtained from bones, in which it exists combined with lime. The bones of a full-grown person contain between one and two pounds of this inflammable substance.

Phosphorus is generally sold in the form of small cylinders. It is white, and has a waxy look. It has so strong an affinity for oxygen that it is kept in water. Exposed to the air, fumes arise from the surface. This results from its uniting with the oxygen of the air. This smoking is really a slow burning; and if it be in a dark place, light is given out. Phosphorus takes fire with so little heat that it is necessary to be very cautious in experimenting with it. You should always cut it under water, and on taking a piece out you should hold it with a pair of pliers or on the point of a knife.

Some of the experiments that can be tried with phosphorus are pleasing, but dangerous: at least, you must not try them without the aid of an experienced person.

To prepare for these, put a piece of phosphorus, of the size of a small pea, into a bottle containing half an ounce (a table-spoonful) of ether. Cork the bottle, and let it stand for some days, giving it a shake occasionally. The liquid is a solution of phosphorus, and is ready for use.

Drop some of this solution upon the hands, and rub them briskly together. The ether will fly off in vapor, leaving the phosphorus on the hands. If you do this in the evening, and make the room dark, your hands will be covered with light. The reason is, that the phosphorus unites with the oxygen of the air, producing combustion. If you rub your hands, the light will increase, because the fire is made to burn more briskly. But what is the reason that the hands are not burned in doing this? It is because there is so little of the phosphorus that very little heat is produced.

Moisten a lump of sugar with the solution of phosphorus, and drop it into hot water. The heat of the water sends both the ether and the phosphorus up to the surface, and, when they get there, the oxygen of the air sets fire to the phosphorus, and this sets fire to the ether, and off they go in a flame together.

Pour some of the solution upon some fine blotting-paper. The ether evaporates, and, after it is all gone, the phosphorus takes fire and consumes the paper. If the blotting-paper be laid upon something hot, the phosphorus and ether will burn together, just as in the preceding experiment.

Phosphorus can be made to burn under water; but we advise you not to try the experiment, because the materials required are dangerous to handle.

Phosphorus is so eager to unite with the oxygen in the air that a little friction produces heat enough to make it unite with it, and so quickly as to burn. For this reason, phosphorus is one of the ingredients of the substance on the ends of matches.

When phosphorus burns, it forms a snow-like substance, which dissolves very readily in water, forming phosphoric acid. Sulphur, you know, by a certain process, yields sulphuric acid, and phosphorus yields phosphoric acid. It is this substance combined with lime that makes up the chief part of bones.

Phosphorus is very poisonous when taken into the stomach.

It has happened several times that little children have been poisoned by chewing the ends of matches.

Phosphorus combines with hydrogen, forming a gas having a strong odor, resembling garlic. This gas has the very curious property of taking fire of itself when it mixes with air, and burning with a bright yellow light, while beautiful smoke-rings are formed if circumstances are favorable. It is rather too dangerous a gas for beginners to experiment with; but we shall tell you how to make it in the next book of chemistry.

It is this gas which causes the light called "will-o'-the-wisp," sometimes seen at night over marshy land. Its chemical name is *phosphureted hydrogen*.

Questions.—Describe the nature and occurrence of sulphur. What is the chemical name of "fools' gold?" What is said of there being sulphur in plants and animals? Describe the melting of sulphur. Tell about sulphuric acid. What happens when sulphuric acid and water are mixed? What experiments prove this? What takes place when a piece of wood is dipped into sulphuric acid? What gas gives the bad odor to spoiled eggs? How can it be made? How and where does phosphorus occur in nature? What is its appearance as usually sold? What is said of the danger of handling it? Describe some experiments with a solution of phosphorus in ether. What acid does phosphorus yield? What is said of its poisonous qualities? What peculiar property has the gaseous compound of phosphorus and hydrogen? What is the "will-o'-the-wisp?"

CHAPTER XVII.

SALTS, SULPHATES, ETC.

The term *salt* is applied by chemists to many substances besides our common table-salt. You have probably heard of Epsom *salts*, used as a medicine, and of *salt*petre, used in the manufacture of gunpowder; but perhaps you never thought of these substances as in any way related to common salt. Then we have Glauber's salts, salt of sorrel, salt of lemons, Rochelle salts, and a great many more. Now, these are old-fashioned names of things which have also scientific names; and since the latter explain something of the composition of these bodies, they are much to be preferred. We shall now try to explain the nature of the class of bodies generally called salts.

You learned in Chapter IV. about nitric acid, and in Chapter XVI. about sulphuric acid; but we have not described a pretty experiment which can be made with these or any other acids, and which will help us to understand what follows. By boiling pieces of blue cabbage, or, better, certain lichens, with water, a blue solution is obtained commonly called *litmus*. The smallest amount of nitric acid added to this blue solution turns it bright-red, and all acids act in the same manner. A few drops of the strong blue solution will color a tumblerful of water light-blue, and a single drop of the stronger acids will change this color to red. Now, this red solution may be changed back to blue again by adding soda, potash, ammonia, or any other *alkaline* substance. This change from blue to red, and back again, may be made many times in the same solution, the acid turning it red, and the alkali blue.

If you prepare two solutions, one of potash, and the other of nitric acid, and add a little litmus to each, and then mix the solutions carefully, you will find that it is possible to reach a point when a single drop of either the acid or the alkaline solution will change the color from red to blue, or from blue to red. The acid, as we say, *neutralizes* the alkali.

If you pour this mixture into a proper dish and boil out most of the water, and let the rest cool slowly, you will obtain crystals of a substance made up of nitric acid and potash, called by chemists *nitrate of potash*, and which is commonly known as saltpetre. This substance, on drying, will burn and sparkle in a lively manner if thrown on red-hot coals, a property which is possessed by neither the nitric acid nor the potash alone; so we have here another example of chemical union, about which you learned in Chapter XV.

The saltpetre, being made from nitric acid and potash, is called nitrate of potash. Had we used sulphuric acid in the place of nitric acid for the above experiment, we should have obtained *sulphate* of potash; and, on the other hand, had we used soda instead of potash, we should have *nitrate* or *sulphate of soda.*

Substances which are neither acid nor alkaline, and which yet contain the main ingredients of both acids and alkalies, like the sulphate of potash, are called *salts.* You will find, on studying a more advanced book on chemistry, that this definition is not strictly correct, for some *salts* are very acid; but the ordinary salts, of which we shall speak, are chiefly included in it. What we want you to particularly notice is the manner in which these substances are named: the syllable *ate* is added to the name of the acid, and the name of the *base*, as it is called, is written after it or just before it. Thus, soda and nitric acid unite to form nitrate of soda, or sodium nitrate; potash and phosphoric acid form potassium phosphate; iron and sulphuric acid, iron sulphate; and so on.

In describing the manner in which nitric acid and potash *neutralize* each other, the two solutions were mixed in the presence of litmus merely for the purpose of ascertaining when enough of each had been added: you must not imagine that all salts are prepared in this way. Many substances called by the chemist salts occur ready formed in nature, and we shall tell you about some of these in this and the following chapters.

One of the most abundant of the salts of sulphuric acid is the sulphate of lime. This is sometimes called gypsum, and sometimes plaster of Paris. It received this latter name because there are immense quantities of it near Paris, and it was first used in that city as a plaster.

Sulphate of lime is a very mild substance, and yet it is made of two very active substances. Lime is quite caustic, and sulphuric acid is one of the most corrosive substances in the world. Mix lime, as the gardener sometimes does, with weeds, and it will rot them quickly by its caustic power; and if you drop sulphuric acid upon your skin, it will eat it. But let the sulphuric acid and the lime unite, and you have a substance that you can handle, and, when powdered and wet, you can mold it with your fingers. Here we have one of the most striking illustrations of the fact so frequently seen, that a substance may be wholly unlike the ingredients that compose it.

Some of the forms in which gypsum is found in nature are very beautiful. The alabaster, which is cut into vases and other ornaments, is one of them. Sometimes this mineral is arranged in delicate white fibres, and then it is called *satin spar*. It is well named, for it is as elegant as satin. Sometimes it is in very thin leaves, laid closely together, and at the same time it is as clear as water. It is then said to be *foliated*, a word which comes from the Latin word that means leaf. The common word foliage comes from the same source.

Gypsum is used in powder for a variety of purposes. In using it, the fact that one-fifth of the substance is water is of great service. We will tell you how this is. Suppose that you wish to make a plaster cast. You subject the powdered gypsum to considerable heat to drive off this water in it. Then you wet it so as to make a paste of it. With this paste you mold your figure. Then you let it stand till it becomes dry and hard. Observe what happens. Does the plaster merely dry as a wet cloth does? that is, does the water which has been mingled with it pass off into the air? Some of it does; but a large part of it becomes a part of the plaster. The gypsum really takes to itself, and makes a part of its solid self, exactly as much water as it lost when it was heated. It is precisely as the quicklime takes up water, as stated on page 76.

You can take very pretty copies of coins or medals with this plaster. You can buy a little of it from which the water has been expelled. Moisten some of it, and put it into a small round paper box. Large-sized pill-boxes will answer. Press now a coin upon the surface of the plaster. When the plaster is dry and hard, take the coin off, and you will see a good impression of it in the plaster. To prevent the coin from sticking to the plaster, oil it very slightly.

The hard-finish which is put upon our walls is made of this plaster from which the water has been driven off. First the wall is plastered with common lime mortar. Then some of the powdered gypsum is stirred up in water, so as to make a thin paste, and this is nicely spread upon the wall and left to harden.

Sulphuric acid united with soda forms a sulphate of soda, or Glauber's salts, as it is called. This salt forms large white crystals. With magnesia, sulphuric acid forms sulphate of magnesia, which is called Epsom salts. This is in the form of very white small crystals. It is really a very pretty substance, but it has a bitter, disagreeable taste, as you may well know if you have ever taken any of it as a medicine. Both of these salts are called *neutral* salts, for the acid properties of the sulphuric acid are wholly neutralized in them.

You can try a pretty experiment with sulphate of copper. Dissolve some of this salt in a little water. Hold the blade of your knife in the solution for a few minutes. On taking it out, you will find it covered with a red coat, which is metallic copper. This is because the copper leaves the sulphuric acid and takes the place of the iron, the latter dissolving in the acid.

Nitrate of potash, formed by the union of nitric acid and potash, is commonly called either nitre or saltpetre. It is chiefly interesting as being one of the ingredients of gunpowder. This article is made of three things: nitre, charcoal, and sulphur. They are very carefully mixed. When fire is touched to this mixture, it readily burns, and a great quantity of gas is suddenly produced. It is this gas, striving to get room for itself, that drives the ball out of the gun or cannon, as has been explained in the Third Part of the Child's Book of Nature.

But how is this gas produced? The nitre contains nitrogen gas, and a great deal of oxygen gas. When the powder burns, the latter quickly unites with the carbon, forming a great amount of carbonic acid gas; and at the same time the nitrogen gas is set free. Carbonic acid gas and nitrogen are, then, the chief gases set free in firing gunpowder, and produce the explosion.

How great is the change in this case! From a small quantity of powder comes out, all at once, a very large bulk of gases. We say comes out, for the gases in that powder were locked up, and squeezed, as we may say, into small quarters.

Questions.—Name some substances called salts. Describe the experiment with a solution of litmus. Explain how potash and nitric acid neutralize each other. What salt is obtained by evaporation of the mixture named? Explain the general manner of naming salts. What salt is formed by soda and sulphuric acid? What by iron and nitric acid? What is gypsum? How does it occur in nature? What is satin spar? Of what use is gypsum? Tell how models of medals and coins are made. What is the substance known as Glauber's salts? Describe Epsom salts. Show how copper will coat a steel blade of a knife. Of what is gunpowder made? What gases are set free when it is burned? Why does it explode?

CHAPTER XVIII.

LIMESTONE, SHELLS, AND CORALS.

You will perhaps be surprised to learn that chemists call marble a salt. It certainly has no taste like salt, for it is but little soluble in water; but since it contains a base and an acid, it is classed among the substances called salts. You learned in Chapter VI. that chalk and marble are made up of lime and carbonic acid; and you remember that the carbonic acid gas could be set free by pouring over the pieces of marble an acid called hydrochloric. Since marble contains the above-named ingredients, its chemical name is carbonate of lime. You would hardly suppose that such hard substances as marble and limestone could be composed of exactly the same things as the soft, crumbling chalk; but we have many examples like this.

Limestone and marble are merely different varieties of carbonate of lime; they vary in their granular structure, and sometimes the former contains a little carbonate of magnesia, but this is not essential. Whole mountains are made up of limestone, and in some parts of the country no other rock is found for miles around. So you see carbonate of lime is a very abundant substance. Sometimes the limestone appears in beautiful crystals, transparent and shining; one variety is called *dog-tooth spar*, from a fancied resemblance. Perhaps you have seen specimens of this mineral.

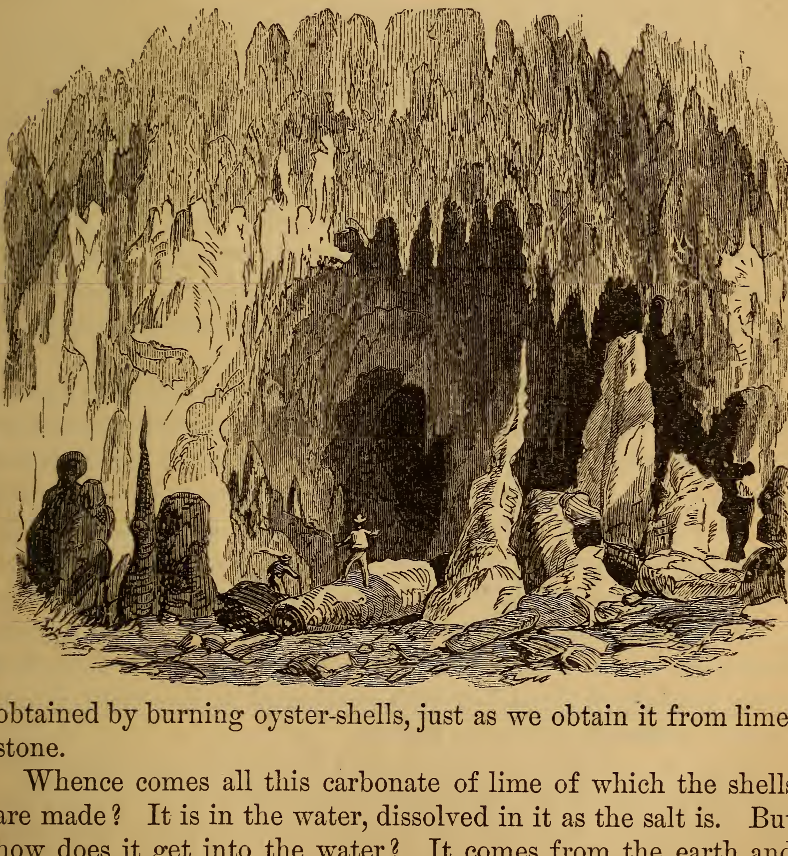
Carbonate of lime does not readily dissolve in water; but water will dissolve some, especially if there be carbonic acid gas in the water. The water that comes from some springs has, for this reason, considerable of this salt in it, and some of it is deposited upon stones and sticks above the spring, crusting them over. In some caves in limestone regions we have beautiful displays of the formation of limestone from water in which this salt is dissolved. As the water drips from any spot in the roof of the cave, some of the carbonate of lime stays upon the roof. Then, as more and more adheres, a projection is formed pointing downward, very much like an icicle as water drips in cold weather from the eaves of a house. At the same time, there is formed underneath, on the floor of the cave, a little hillock of the limestone from the water that drops there. That which forms above is called a stalactite, and that below a stalagmite.

Sometimes, when there are many of these stalactites and stalagmites, and they have been forming for a long time so as to reach a great size, they present a splendid appearance. In Fig. 32, you have a picture of a celebrated grotto in Cuba. Here the stalactites and stalagmites present every variety of form and arrangement, and, lighted up with torches, the place looks like a scene of enchantment.

When limestone is heated in a furnace, the carbonic acid flies off and quicklime remains. Quicklime, you remember, is really an oxide of a metal called calcium.

The shells you pick up on the sea-shore are made of carbonate of lime. All oyster-shells are made of this substance. The lime which is used for making mortar and for other purposes is often

Fig. 32.



obtained by burning oyster-shells, just as we obtain it from limestone.

Whence comes all this carbonate of lime of which the shells are made? It is in the water, dissolved in it as the salt is. But how does it get into the water? It comes from the earth and the rocks of limestone. It is washed along with the water as it runs in brooks and rivers, and at length comes to the sea. Here there is more of it in the water than anywhere else.

But how is this carbonate of lime made into shells? Does it gather from the water on the outside of the animals that live in them? Does the oyster, for example, merely lie still, and let the shell grow on him by having the carbonate of lime settle upon him by little and little from the water, as it encrusts a stone or a stick in a spring? No, this is not the way. All that big rough shell has been swallowed by the oyster, and has been in its body. Only a little at a time was swallowed, dissolved in the sea-water in which it lives; but that little was used in building the shell-house.

Look at an oyster-shell carefully. There are different layers. The outside layer is smaller than the next one, and this is smaller than the next, and so on; and the one next to the oyster is the largest. The outside layer was made when the oyster was very small—a baby oyster, as we may say. Then, as he grew a little larger, another layer was formed from the carbonate of lime as it oozed out from his body, and so on to the last and largest.

All shells are not made exactly after the plan of the oyster-shell; but it is as true of them all as it is of the oyster-shell, that every particle of them has been swallowed in the water drunk by the animals that lived in them.

There is one class of animals that live in the sea which make a singular use of the carbonate of lime they continually swallow. We mean the coral animals, as they are called. These little animals always stay exactly where they are born. They are fixed to a strong foundation. That foundation is their skeleton, formed from the carbonate of lime which they have swallowed. This skeleton extends up into the animal's body. The animal is all the time growing upward in the water, and adds continually to the top of its skeleton. In the mean time, the lower part of its body is always dying. It dies below while it grows above.

You see what the effect of all this is. The animal builds a column of carbonate of lime, he being all the time at the top of it, sitting on it like a well-fitted cap.

But these animals always live and work in companies. If a great many of them, then, build their columns side by side, a great deal of building will be done, though each does but little. Whole islands have been built in this way. Long ranges of coast, sometimes for hundreds of miles, have been lined with reefs built up by these little animals. Some of the tiny builders that do such work are no larger than the head of a pin. Nearly all the foundation of Florida has been gathered from the water by these little reef-builders.

We will show you how this building was done. All along the coast of Florida, a little way out from the main-land, there are islands called *keys.* These have been built up by the coral animals. They began their work down deep at the bottom of the sea, and worked along upward till they reached the surface. Then their work was done, for they can not work out of water; and their work being done, they died.

But something more needs to be done to make these coral reefs fit to live upon, for they are merely plains, as we may call them, of carbonate of lime, which reach just to the surface of the water. After a while they do become real islands, and things grow upon them, and people live there. The waves, dashing over the reefs, break them up somewhat, and the pieces are washed up toward the middle of the reef. At the same time, the various things floating about in the sea collect there, and the sea-weed is thrown up upon the heaps in considerable quantities by the waves. All this gradually forms a soil upon the reef, and makes it a real island. Seeds are dropped there by birds, or are carried there in the water, and are washed up on to the land. Grass, flowers, shrubs, and trees soon grow there, and then man comes and plants such things as he wishes to have grow, and builds his habitation.

Egg-shells are made of carbonate of lime; but hens sometimes lay eggs with no shells on them. Why is this? It is because the hens have not swallowed enough carbonate of lime. They swallow it mingled with their food, the dust of it being scattered about from broken oyster-shells, chalk, etc. As the canary-bird pecks away at the cuttle-fish bone that hangs in its cage, some of it becomes mingled with its food, and, being swallowed, is used in making the shells of the eggs that the bird lays.

Questions.—What is marble made of? Why is it called a salt? What is the difference between marble and limestone? What happens when water containing dissolved carbonate of lime drips from the roof of a cave? What are stalactites? How is quicklime made? Of what are shells made? How is lime obtained from shells? Whence does the carbonate of lime in the water come? How is it made into shells? Describe the manner in which the shell of the oyster is formed. What is said of the formation of shells generally? Describe the manner of the growth of the coral animal. What is the result of this process? What is the result if many of them are along-side of each other? What is said of the extent of their building? What is said about Florida? When the coral animals have finished their work, how are their reefs made into islands? What is said of egg-shells?

CHAPTER XIX.

PEARLASH AND OTHER CARBONATES.

There are a great many carbonates besides carbonate of lime or limestone, and some of these we shall now describe.

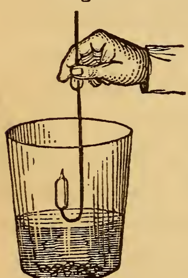
Carbonate of potash, commonly called pearlash, is a very different substance from carbonate of lime. It dissolves in water very readily. It is obtained from the ashes of plants; the plants taking it up from the soil. Not many years ago it was common for every family in the country to have what was called a leach-tub. In this were put the wood-ashes. Water being poured over the ashes, there ran out, from a hole below, a liquid called lye. This contained the carbonate of potash and caustic potash together in solution. There is caustic potash as well as the carbonate, because the ashes contain lime. The explanation is this: Lime, having a greater affinity for carbonic acid than pearlash, takes away this gas from some of the carbonate, thus changing it into caustic potash. The quantity of the caustic potash in the lye is increased by putting some lime into the bottom of the leach-tub. The effect of this is to change much more of the carbonate of potash into caustic potash than would be changed by the little lime in the ashes. Leach-tubs are now much less used by families, as pearlash is made from ashes mostly in large establishments.

This mixture of carbonate of potash and caustic potash is called simply potash by most people, but this is not strictly correct, for this name belongs properly only to caustic potash.*

We have told you that if carbonate of lime be heated strongly, the carbonic acid will be driven off. Carbonate of potash is very different in this respect. The hottest fire can not drive off the carbonic acid from it. If heat could do it, we should not have any carbonate of potash in ashes, but caustic potash, the carbonic acid having been carried off into the air.

Here is a little experiment that you can try with carbonate of potash. Drop a tea-spoonful of this salt into a tumbler half full of vinegar. There will be a brisk effervescence, a gas escaping from the liquid. Now lower a burning taper into the tumbler, as represented in Fig. 33. The flame will be extinguished. Why? Because the gas which rises and fills the tumbler is carbonic acid. The acetic acid in the vinegar takes the potash away from the carbonic acid, and a salt is formed by the union of the acetic acid and the potash. You can tell what the name of it is by observing what we have told you about the names of salts on page 98.

Fig. 33.



If you dissolve some potash in water, and then boil in the solution some dirty greasy rags, the solution will become very dark and dirty, but the rags will be white and clean. The potash combines with some of the ingredients of the grease, and the new compound dissolves in the water; but in uniting, the dirt

* Caustic potash is one of a class of bodies called *hydrates*, concerning which details will be found in Hooker's Chemistry, Science for the School and Family, Part II.

has been taken out of the cloth, with the grease, by the potash. This explains the use of soap in washing. In making common soft soap the potash is united with grease or fat and water, but there is not so much grease as to prevent the potash from uniting with more grease. The potash alone would be a very harsh material to wash with, but by mixing it with grease and water we make a very smooth article that we can use easily. In washing clothes, the potash in the soap takes out all the oily matter which has come from the perspiration, and with it the dirt; and if there be dirt alone without any oily matter, the soap readily mingles with it, so that the water can take it out better than it can without the soap.

Water and oil, you know, will not mix, no matter how much or how long you may shake them together; when you stop shaking them in a vessel, they gradually take their places, the water sinking and the oil rising. But if you pour in a solution of pearlash or potash, and shake again, it acts upon the oil, forming with it soap, which then dissolves in the water.

Besides the ordinary carbonate of potash, there is another commonly called the bicarbonate, or *saleratus*. This is often used for raising bread and cake, some acid being added to drive out the carbonic acid gas; and this gas set free, everywhere in the dough makes little spaces or cells, swelling it up. Sour milk is often used, since it contains enough acid to decompose the bicarbonate of potash.

Carbonate of soda is a very important and useful substance. It was formerly obtained by leaching the ashes of certain seaweeds, but is now made more cheaply from common salt. It forms transparent crystals which crumble to a white powder. When dissolved in water, it forms an alkaline solution, soapy to the touch, and which turns reddened litmus solution blue. Its uses are so numerous that we can not tell you half of them: for washing greasy things it is stronger than soap; hard soap itself is largely made from it; and it is used in making glass, as will be shown in the next chapter.

One sort of carbonate of soda, commonly called the *bicarbonate*, is used for making home-made soda-water. The manner of using the white powders sold by druggists for this purpose has been already explained on page 38, but you are now better prepared to understand the chemistry of the operation. When the solution of bicarbonate of soda is mixed with the solution of tartaric acid, an exchange of acids ensues; the carbonic acid leaving the soda and going off with effervescence, while the tartaric acid combines with the soda, forming tartrate of soda. This remains in solution, and has no injurious effect on persons drinking the soda-water.

There is a carbonate of magnesia. This is the common magnesia used in medicine. If this be heated very thoroughly, the carbonic acid will be driven off, just as it can be driven off from carbonate of lime or chalk. This changes the carbonate into an oxide of the metal magnesium. This oxide is the so-called *calcined magnesia*, which very probably you have taken as medicine.

The carbonate of lead is the "white lead," so called, used so much in painting. This is a very poisonous salt. It is often formed in the lead pipes used for conveying water; and as it is somewhat soluble, it is carried into the system of those who drink the water, and gradually produces painful disease, which sometimes ends in death. What appears at first thought singular is, that the purer the water, generally the more apt is this salt to form. This is, however, easily explained. When the water is not pure it commonly has some substances in it which act on the lead in such a way as to form a thin coat which is not soluble in the water. This prevents the oxygen and carbonic acid in the water from acting upon the lead. Fortunately, the substances dissolved in water are usually such as to make the fixed coating, and therefore most waters can be safely carried through lead pipes, though tin-lined lead pipes are better.

Smelling-salts, with which you may be familiar, is the common name given to another carbonate, carbonate of ammonia. This substance is prepared on a large scale by heating in closed iron vessels bones, hartshorn, and other animal matters, and then purifying it by sublimation. It is used in medicine, and in the chemical laboratory.

Questions.—How is pearlash made? For what is lime added? How does vinegar act on carbonate of potash? Why does potash clean greasy articles? Why does it make oil and water mix? What is saleratus? How is carbonate of soda made? Of what use is it? What is said of the bicarbonate of soda? Explain the chemistry of making soda-water. What salt remains in solution? What of the carbonate of magnesia? Of carbonate of lead? Explain the danger of using lead pipes for conveying drinking-water. What are smelling-salts? Of what are they made?

CHAPTER XX.

GLASS AND EARTHENWARE.

THE beautiful, white, shining particles of sand seen on the sea-shore or elsewhere, the brown flint, the clear rock-crystal which often occurs in symmetrical forms, and the various sorts of agates, are all made of one and the same thing, called by chemists *silica*. Silica is the oxygen compound, or oxide, of a substance called silicon, which is, however, never found as such in nature. Is not this curious? Silica, so abundant in sand and rocks, and yet silicon itself never occurring? But this is not the first case we have met of a similar nature. Lime, you remember, is an oxide of the metal calcium, and the latter is never found in nature, though limestone is so common.

Silicon is not a metal, but a substance somewhat resembling carbon, and the oxide silica is nearly related to the oxide of carbon you have learned to call carbonic acid; consequently, silica is often called *silicic acid*, though there are scientific reasons for disapproving of this name. Silicic acid unites with potash and soda and lime, forming bodies called *silicates*, just as carbonic acid forms carbonates. The silicates of lime and soda constitute glass.

You know that in making mortar we put in sand with the lime. This gives firmness to the mortar. Lime and water would not answer alone. But the sand has another effect: the longer the mortar or plastering remains, the harder does it become; and very old plastering, as we see in tearing down old houses, is very hard indeed. This is because the silicic acid in the sand gradually unites with the lime; so that, in the course of years, there comes to be considerable silicate of lime in the plastering.

Glass is not one silicate alone, commonly, but a compound containing two or more silicates. Thus, common window-glass is a silicate of both lime and soda together. To make it there are melted together, with a very hot fire, fine nice sand, old glass, limestone, and soda. Limestone, you know, is carbonate of lime. The heat drives off the carbonic acid, and the lime, released from this acid, unites with the silicic acid of the sand, forming silicate of lime. At the same time the soda combines with this acid, making silicate of soda, and the two silicates, uniting in one, form a silicate of lime and soda. The different kinds of glass are, you know, insoluble; but there is a way of making glass that will dissolve, and it is used as a fire-proof varnish.

The various colors of glass are made by various oxides of metals mingled with the melted glass—oxides of iron, copper, manganese, etc.

It is stated in a very old book that the making of glass was discovered by accident. Some people going on a voyage were driven on shore at a very sandy place. There was a great deal of sea-weed, which had been thrown up upon the shore, and had dried in the sun. With this they made a fire on the sand, and it was observed that there was mingled with the ashes some substance that was hard, and had a glassy appearance: it was really glass. You see the explanation of this. The ashes furnished the alkali and the sand the silica to make the silicate, that is, the glass. If this be all true, it is one of many examples which we have illustrating the fact that a vast deal can be often learned by thinking about the common things that we happen to see. A glassy appearance in the ashes of sea-weed most people would not spend a thought upon; but an observer inquires what causes this appearance, and, in pursuing the inquiry, perhaps makes a valuable discovery. Be not, then, mere sight-seers as you go through the world, but observers; and observe little things as well as great.

All earthenware contains clay. It is quite pure in porcelain, and very impure in common flower-pots, and especially in bricks; that is, it is mingled with other things, sand, etc.

Clay, like glass, is a silicate. Perfectly pure clay is a silicate of alumina. But all clay, as we find it, contains more or less of other silicates—of lime, of potash, etc.

The brownish-red color of bricks and common flower-pots is owing to the rust of iron in the clay.

Bricks, you know, are quite porous, and consequently will absorb water. This is also the case with common flower-pots. This porousness will do us no harm in this case, but generally it is necessary to have earthenware so made that no fluid can escape through its pores. It would not answer, for example, to keep preserves in jars of porous earthenware. The watery part would gradually escape through the pores, and the preserves would become dry.

The difficulty is remedied in two ways. One is to *glaze* the surface of the earthenware; that is, a glass surface is made.

This is done in various ways. One method you will be interested in, because you can understand the chemistry of it. The fumes of common salt are made to envelop the articles of earthenware when they are very hot. Now, salt is composed of a gas (chlorine) and the metal sodium, as we shall explain more particularly in the next chapter. You learned something about sodium in Chapter XIII. In the glazing, the chlorine leaves the sodium to unite with some of the iron in the earthenware. Then the sodium, thus left by the chlorine, unites with the silica in the earthenware to form a silicate of soda, thus making a soda glass, as we may call it. So you have a coating of this glass all over the articles.

Another mode of making earthenware impervious to water is to make the ware partly earthen and partly glass. The ingredients are so selected that the silicates of lime, potash, etc., of which glass is made, are thoroughly united with the silicate of alumina, or clay. This stops up all the pores, and does not merely shut those which are outside, as the glazing does.

Silica is a very important part of some plants. It is in the stalks of all grass, giving them such firmness that they can stand up. It is also in the stalks of all grain. It is to these and some other plants very much what bones are to animals. In some plants there is so much silica that they are used for scouring.

But how does this silica get into plants? Even if you make it very fine indeed, and put it into water, none of it will dissolve. It seems strange, then, that any of it should go with the sap up into any plant. To do this, it must be made very fine, much finer than we can make it by pounding and grinding; and this is done in some way, we know not how, about the roots of plants. But this is not enough; it must be changed so as to make it dissolve in water, or it will not go up in the sap; and this is done by means of the potash that is in the ground with the silica. But little is required, and that little is furnished dissolved in the sap. And then, as it goes up, it is lodged just where it is wanted in the stalk. None of it gets by mistake into the kernels of the grains. If it did so, our flour would be gritty, and our teeth would soon be worn out.

Questions.—Of what is sand composed? What other substances are made of silica? What is silicon? With what does it combine? Tell about silica in mortar. What are the salts made by silica called? What is common window-glass? Tell how it is made. What is said of soluble glass? How are the various colors of glass produced? Relate the anecdote about the discovery of the way to make glass. Of what is earthenware made? What is the composition of pure clay? What else is there commonly with it? What is the cause of the brownish-red color of flower-pots and bricks? What is said about their porousness? What is glazing, and what is the use of it? Describe and explain glazing with salt. Describe another way of making earthenware impervious to water. What is said of silica in plants? How does it get into them?

CHAPTER XXI.

CHLORINE AND COMMON SALT.

THE salts noticed in the previous chapters contain oxygen; but there are some salts in which there is no oxygen. They are formed by the union of certain simple substances with a metal. Common salt is one of these salts. In this substance the metal sodium is united with a very singular gas called chlorine, and so the chemists call it the chloride of sodium.

You remember that all the compounds of the gas oxygen formed with metals are called oxides, so all the compounds of this gas chlorine are called chlorides.

Before we tell you particularly about salt, we shall speak of the gas chlorine. It is one of the gases that have color. Its color is a greenish-yellow. It has a powerful and very peculiar odor, and, if breathed, is very injurious. Even when diluted with considerable air, it is very suffocating. If you should breathe it without any air mixed with it, you would die.

Chlorine is of great use in purifying foul air. You, perhaps, have seen chloride of lime exposed in rooms where there is sickness of such a kind as to cause bad odors. It is the chlorine arising from this that purifies the air. The little chlorine that escapes into the air in this case, although you smell it quite strongly, does not interfere with your breathing, for it is very largely diluted with air.

The odor of this gas is so peculiar that if you have ever smelled it once, you always know it afterward. You smell it in manufactories where there is bleaching of cloth going on. You smell it, therefore, in paper-mills, for the rags out of which the paper is made are bleached by it.

We will tell you about this bleaching. If you put a rag of calico into a jar of chlorine gas, no effect will be produced on its colors; but moisten the rag before it is put in, and the colors will be taken out by the chlorine at once. Chlorine must have water present, or it will not bleach.

Chlorine gas will dissolve in water, and the solution is very convenient to use in bleaching. A calico rag dipped into it is very soon made white. It will take out ink-spots also. It has no effect upon printers' ink, however, for the latter contains lamp-black.

You see the great usefulness of chlorine in making paper. White paper can be made out of rags of all colors, because the colors can be removed by the chlorine. You see, too, its usefulness in whitening cloth. The old method of doing this was very slow. It was to spread cloth out upon grass for the sun, and rain, and dew to whiten. This, called *grass-bleaching*, took weeks; but, with the *quick bleaching* by chlorine, the same thing is done in a few hours. Some care is required not to have the chlorine water too strong, and to get all the chlorine out of the cloth after the bleaching is done. If this care be not exercised the cloth will lose some of its strength, some of the substance of the cloth being eaten out, as well as the coloring matter.

A convenient way of making chlorine without much apparatus is the following: Pour into a pint bottle two table-spoonfuls of dilute sulphuric acid, and add a little more than the same quantity of chloride of lime, or bleaching powder. Add the powder gradually, covering the bottle with a slip of glass each time after dropping some in, as represented in Fig. 34. Chlorine made in this way, though not pure, will answer for many of the experiments.

Fig. 34.

The explanation is this: The sulphuric acid unites with the lime, and the chlorine, being thus separated, rises and fills the bottle.

Another method is to put some black oxide of manganese into a flask, and pour in enough hydrochloric acid to cover it, as seen in Fig. 35. Gentle heat must be applied, and the gas will pass over into the bottle which is placed to receive it. You observe that the tube reaches to the bottom of the bottle. This is to have the chlorine gas push up the air which is in the bottle, which it readily does, taking its place in the bottle. It is two and a half times as heavy as air, and so has no disposition to escape upward. You can tell when the bottle is full by the color. When it is full, slip it out from under the tube, cork it, and place the tube in another bottle.

Fig. 35.

In this method of obtaining chlorine the gas comes from the hydrochloric acid, an acid of which we shall tell you more presently. It is the same acid we used in making carbonic acid from marble, as explained in Chapter VI.

Although chlorine gas is so destructive to life when breathed, it supports combustion. If a taper (Fig. 36) be introduced into a bottle of this gas, it burns with a dull-red flame, and a thick cloud of smoke. The explanation is this: Chlorine has a strong affinity for hydrogen, and but little for carbon. It therefore unites with the hydrogen of the taper or candle, and the flame, heating the carbon that is with the hydrogen in the taper, sends it upward in a dense smoke.

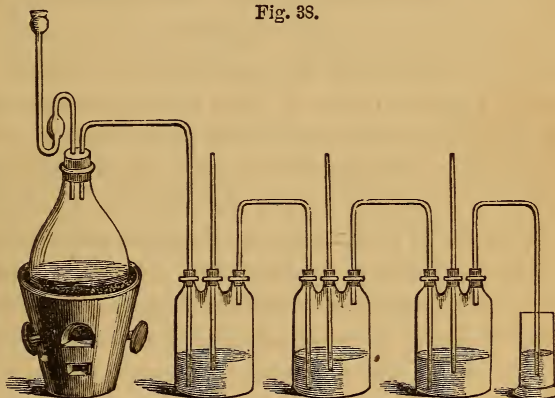
Fig. 36.

So, also, if a slip of paper, moistened with oil of turpentine, be introduced into a bottle of chlorine (Fig. 37), the hydrogen of the turpentine will burn, while its carbon will pass off unburned in smoke.

Fig. 37.

We have just mentioned that hydrogen combines with chlorine, but we have not told you what substance is formed by their union. It is the "hydrochloric acid" which we have several times mentioned. You see the first part of the name comes from *hydrogen*, and the last from *chlorine*, its name thus indicating its composition. Hydrogen gas, you know, is the lightest known substance, and burns with a very hot flame; chlorine you have just learned about. Now, there is one thing very curious about these two gases when they are mixed together. If they be mixed in the dark, and be kept there, they have no disposition to unite; but bring the mixture into the light, and the union takes place, forming the acid. If a beam of sunlight be thrown by reflection from a looking-glass upon the glass jar containing the mixture, the union is so rapid as to cause a violent explosion. This is a dangerous experiment, and we advise you not to try it. A simple and safe way of making hydrochloric acid is to heat common salt with sulphuric acid in a flask: the gas rises, and may be collected in bottles, or caught in water, in which it is very soluble. Fig. 38 represents an apparatus for obtaining a quantity of the gas dissolved in water. The materials are placed in the flask at the left hand, and heated over the small furnace; the gas passes out through the small tube into the first three-necked bottle which contains some water. When the water in this bottle will absorb no more, the gas passes over into the second bottle, and so on. The gas has a suffocating odor, but not so strong as chlorine, nor so disagreeable in its effects.

Fig. 38.



What we commonly call hydrochloric acid is this solution of the gas. A mixture of this acid with nitric acid is called *aqua regia*, that is, royal water, because it is the only liquid that will dissolve gold, the king of metals. It is very curious that neither of these strong acids alone can affect the gold; but let them make the attack together, and this king submits at once. The gold, in dissolving, is changed into a chloride of gold.

See how very widely both of the ingredients of common salt differ from the compound which they make. Chlorine is a gas of most powerful odor, very suffocating, so that to breathe it undiluted is to die. Sodium is a metal which, if put on your tongue, would take fire, and act as a caustic. Yet this gas and metal together form a very mild, pleasant salt, which is a part of the food of man and beast everywhere.

Salt is a very abundant article in all parts of the world. There are large quantities of it dissolved in sea-water. In some parts of the world there are vast deposits of solid salt. The most famous are those of Poland and Hungary. In the salt-mines of Cracow, though salt has been taken from them for over six hundred years, it is supposed that there is still enough to supply the whole world for centuries to come. Some parts of these mines have been shaped into beautiful forms of various kinds as the salt has been taken out. Chapels, halls, etc., have been made, the roof being supported by huge pillars of salt. When lighted up by lamps and torches the appearance is very beautiful.

Large lakes of very salt water exist in many parts of the earth. There is a remarkable one in this country called Great Salt Lake.

In this country most of our salt is obtained from salt-springs. The most noted are those of Salina and Syracuse. In the best of the springs there is a bushel of salt in every forty gallons of the brine. This is between eight and nine times as much as there usually is in sea-water. To get the brine from the springs wells are dug, and the brine is pumped up by machinery, and conducted by troughs to boilers. Here the water is driven off by heat.

Sometimes the salt is obtained from the brine by a slower process. The brine is exposed to the sun in extensive shallow vats, and the water gradually passes off into the air, leaving the salt behind. Salt is often obtained in this way, in hot climates, from sea-water.

There are a great many chlorides besides the chloride of sodium, for chlorine unites with many of the metals. With some it unites with such eagerness that they burn together. Thus, if you sprinkle a fine powder of the metal antimony into a jar of chlorine gas, each particle will take fire. You will therefore have a shower of fire in the jar, and there will be a white smoke. This smoke is composed of very small particles of chloride of antimony, for in the burning the chlorine and antimony unite.

There are two chlorides of mercury, which are very different from each other. One is calomel, and the other is corrosive sublimate. The difference in their composition is that the corrosive sublimate has exactly twice as much chlorine in it as the calomel. The calomel is called, therefore, the chloride of mercury, while the corrosive sublimate is the bichloride. This difference in the proportion of chlorine makes a vast difference in the qualities of the two substances. The corrosive sublimate is very soluble in water, but the calomel will not dissolve at all. The corrosive sublimate is a violent eating or corrosive poison, as its name indicates. Sometimes, from carelessness, this poison has been drunk, and many deaths have been caused in this way. Now, every body ought to know exactly what to do when this accident happens, for what is to be done must be done quickly. The person must be made to swallow very freely of the whites of eggs. This is the best thing; but, if eggs are not at hand, milk, or flour stirred up in water, can be used.

Questions.—What are the chemical name and composition of common salt? What are the properties of chlorine? What is said of its purifying power? What of its odor? What of its bleaching power? Tell about the solution of it. What is the use of chlorine in paper-making? State the difference between grass-bleaching and the bleaching with chlorine. Describe some methods of obtaining chlorine gas. From what does the chlorine come in the second method? Will substances burn in chlorine gas? Of what is hydrochloric acid made? Describe a safe way of obtaining it. What is aqua regia, and why so named? What is said of the difference between common salt and each of its ingredients? What is said of the abundance of salt? What of the salt-mines of Cracow? What of salt-lakes? What of the salt obtained in this country? How is the salt obtained from the water containing it? What slower process is sometimes employed? What is said of antimony burning in chlorine? What of the two chlorides of mercury? What are their common names, and what their chemical names? What should be done in case of poisoning by corrosive sublimate?

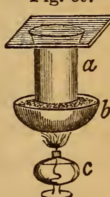
CHAPTER XXII.

IODINE AND SEA-WATER.

There is another substance, similar to chlorine in many respects, in sea-water and in sea-plants. It is called *iodine.* It exists in sea-water combined with the metals sodium and potassium, as chlorine is combined with sodium. In some sea-plants there is considerable of it, and it is from a lye made with the ashes of such plants that it is obtained.

Iodine is a solid substance, looking something like graphite but darker in color. If heated, it turns into a splendid purple vapor or gas, which is one of the heaviest of the gases. If you put a few grains of it in a jar, *a*, Fig. 39, and place the jar in a sand-bath,* *b*, warmed by a spirit-lamp, *c*, the jar will be filled with the beautiful violet vapor. The air in the jar, being very much lighter than the iodine vapor, is pushed up by it out of the jar. When the jar is full of the vapor, place a piece of glass over it, and take it out of the bath.

Fig. 39.

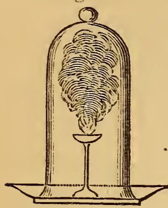


A taper will burn in this vapor, but not so brightly as in the air; but a piece of phosphorus will take fire of itself in it, so eager are the iodine and phosphorus to unite. If some iodine

* A sand-bath is simply fine sand in a dish. The object is to apply the heat gradually. This can be done, however, with a spirit-lamp alone, by keeping it at a little distance from the glass jar.

be placed in a jar upon a little stand, with a bit of dry phosphorus upon it, as represented in Fig. 40, so much heat results from their union that they take fire, and a smoke arises. This smoke is partly the violet vapor of the iodine and partly the white fumes formed by the phosphorus.

Fig. 40.



As chlorine forms chlorides with many of the metals, so iodine forms iodides with them. The iodide of potassium is a very valuable medicine. Iodine forms two iodides with mercury, one of which is of a brilliant scarlet color. The iodide of silver is made use of in photography.

There is another very singular substance in sea-water called *bromine*. This is a very heavy, reddish-brown liquid, giving out deep orange-colored fumes. The quantity of bromine in sea-water is very small. It seems to be quite essential, however, for it is always present. It is also in most salt springs. Wherever there is chlorine, bromine is found with it. It must be of some use in the sea-water, but what we know not. It never exists in the sea-water as bromine, but is always in combination with such metals as sodium and magnesium, making bromides. The chemist can separate it from these.

This very singular substance is a terrible poison. A single drop on the skin eats into it and makes a painful sore. Bromide of sodium is used in photography and in medicine.

The three substances of which we have spoken in this and the previous chapter (chlorine, iodine, and bromine) are the peculiar substances of sea-water. They are always united, however, with other substances, making compounds, chlorides, iodides, and bromides. The reason that the water of the sea has so much of these and various other mineral substances in it is, that in the sea are collected the washings from all kinds of rocks and sand and earth. The different salts thus collected and dissolved in the sea are these: chloride of sodium, or common salt; chloride of potassium; chloride of calcium; chloride of magnesium; sulphate of lime, or gypsum; sulphate of magnesia, or Epsom salts; carbonate of lime, or chalk; carbonate of magnesia. These are always present in sea-water, besides various other substances.

We can learn of what use some of these substances are in the sea. For example, we can see of what use carbonate of lime is. All those animals that live in shell houses, as you learned in Chapter XVIII., need carbonate of lime in the water they drink, so that it may get into their body, and be used in making their shells.

Most of the solid matter dissolved in sea-water is common salt. Next to this in quantity are the compounds of magnesium—the chloride of magnesium, and the sulphate and carbonate of magnesia. It is these that give the bitter taste, especially the sulphate of magnesia, or Epsom salts. If you ever take any of this as a medicine, you will recognize the resemblance between its taste and the bitter taste of sea-water.

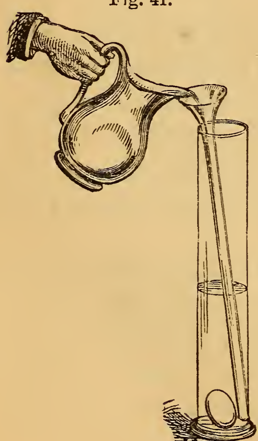
There is a comparatively small amount of these saline matters in rivers, because the water in them is always moving on to empty into lakes and seas. There is usually but little in lakes, because the water is running out of them as constantly as it runs in. Thus the water that runs into our great chain of lakes in the north runs out through the River St. Lawrence into the Atlantic Ocean.

Some inland seas and lakes contain more saline matters than the ocean itself. This is partly because they have no outlet, and partly because there is much salt in the neighborhood. The Caspian Sea, the Dead Sea, and the Great Salt Lake of Utah are of this kind.

All the saline matter in the water of rivers, and lakes, and seas was once in the rocks of the earth, and was carried off by the water, which is everywhere so busy. But, for the most part, before this was done, such matter was in various ways broken off from the rocks, and ground up, so as to make a part of the earth under our feet. Here the water found it, and carried it off into the brooks and rivers and seas.

But much of all this is returned, in various ways, from the water to the earth again. We will give but one example of this. The coral animals, about which you learned in Chapter XVIII., taking the carbonate of lime which the earth has supplied to the water, give it back to the earth in reefs and islands.

Fig. 41.

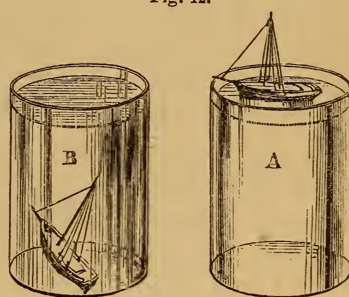


The more salt there is in water, the heavier it is, and the more easily will it bear up solid substances. Thus, a man floating in common water has only a part of his head above the surface; but in the water of the Dead Sea it costs him no effort to keep breast-high in it. A ship there would easily carry a load which would sink it almost anywhere else.

Experiments.

There are some pretty experiments which show the difference between salt and fresh water in regard to floating substances. Suppose that you have an egg in a jar half full of water. The egg will be at the bottom of the jar, for it is heavier than water. Pour now some strong brine into the bottom of the jar through a long tube, as represented in Fig. 41. The brine will force up the lighter water, and with it the egg. The egg will remain at the middle part of the jar, at the bottom of the fresh water, floating on the brine, just as a piece of wood would float on the surface of water in the jar, at the bottom of the air, if the jar were half full of water.

Fig. 42.



A very pretty experiment is represented in Fig. 42. The jar A is filled with brine. A little toy ship, so loaded that it will just float upon the brine, is placed upon it. If now you place the ship in the jar of fresh water, B, it will sink.

Questions.—Where is iodine found? Describe this substance. What are iodides, and what is said of some of them? Describe bromine. What is said of the quantity of it in sea-water? With what is it united? What is said of its poisonous character? To what use has it been applied? What is said of the three substances peculiar to sea-water? What are the solid substances contained in sea-water? Of what use is the carbonate of lime in sea-water? What is said of common salt? What is the cause of the bitter taste of sea-water? What is said of solid matter in the water of rivers and lakes? Mention some inland lakes and seas that are salt. Why are they so? Describe the experiment with the egg. With the toy ship.

CHAPTER XXIII.

SOLUTION AND CRYSTALLIZATION.

The different substances of which we have been writing vary greatly as to their solubility in water: some of them will not dissolve at all, some sparingly, and water will absorb large quantities of some others. Calomel, for example, which is a chloride of mercury, is perfectly insoluble; that is, not a particle of it can be dissolved in water. But corrosive sublimate, the bichloride of mercury, is very soluble. Magnesia is insoluble, but potash is exceedingly soluble. The latter is very eager for water, and if exposed will become dissolved in the water which it gathers from the air. It can be dissolved in half its weight of water; that is, a pound of water will dissolve two pounds of potash. Now, lime absorbs water, but it takes seven hundred pounds of water to dissolve one pound of lime.

The Creator has made this great difference between potash and lime, in regard to solubility, because the difference is needed. For example, we want to use lime in plastering walls; but it would not answer for this if it would, like potash, gather water from the air and dissolve in it. It would be very inconvenient to have the plastering in our houses dissolve and run down whenever it chanced to get wet. But for the uses for which man needs potash it is well to have it dissolve easily. For instance, it is used in making soap, and needs to be soluble for this purpose.

Salt dissolves easily, but not so easily as potash. It would be inconvenient to have it do so. We want to keep salt dry for use, and this we could not do if it absorbed water as eagerly as potash. The Creator has made it soluble to just the right degree to suit the uses for which he designed it. It sometimes troubles us by gathering moisture from the air, but this is only when the weather is damp; that is, when the air has much water in it.

Let us compare two carbonates in regard to solubility, the carbonate of soda and the carbonate of lime. The carbonate of soda is very soluble. This is convenient for the uses to which man puts this salt. But the carbonate of lime, which appears in the forms of chalk, limestone, marble, etc., is very slightly soluble. It would be bad to have it dissolve readily in water. This salt, you know, makes the shells of oysters and other shell-fish. It would not be well to have their shell houses made of a material that the water could dissolve easily. And yet, if carbonate of lime were not somewhat soluble, how could it get into the blood of these animals so that it can be made into shell? You see, then, that the Creator has made this all just right.

But, besides this, it would be very injurious to have so much carbonate of lime in the water as there would be if it were very soluble. The rain that comes down upon chalk and limestone, which here and there form rocks and hills, and even mountains, always washes down a little, and carries it among the particles of the earth, and down streams into the ocean. That little is enough for building the houses of shell-fish and for other purposes. If the carbonate of lime were more soluble, there would be more than enough, and it would give us a great deal of trouble. When well-water is *hard*, it is generally because there happens to be considerable carbonate of lime in it.

Silica is, like carbonate of lime, but slightly soluble. Suppose that it were not soluble at all; all our grass and grain would lie flat along the ground, for it is the silica in them that gives them the firmness by which they stand up.

Commonly, when a substance is soluble, more will dissolve in hot than in cold water, but this is not so with common salt.

When we have made water dissolve just as much of a substance as it can, we call it a *saturated* solution. This word comes from a Latin word which signifies to satisfy, or feed to the full. Water is more easily satisfied or saturated with some substances than with others. Potash and lime are in strong contrast in this respect: half of a pound of water will not be satisfied till it has dissolved a pound of potash, while seven hundred pounds of water will be satisfied or saturated with a pound of lime; that is, it takes fourteen hundred times as much potash as lime to saturate water.

Observe what it is to have a solid substance dissolved in water. Some solid substances you can mix up very thoroughly with water by powdering them well, and yet they do not dissolve. Calcined magnesia is readily mixed with water, but it is not dissolved, and it settles after the water has stood for a little while. But a substance that dissolves disappears. If it have color, you see that in the water, but not the little grains or particles, as you do in the magnesia and water. A perfect solution is generally clear and transparent. The substance dissolved is much more finely divided up than when it is merely mixed in the water; and if the solution be left to stand, the solid substance remains, as we may say, hidden among the particles of the water.

Somewhat in the same way that water dissolves solids, air dissolves water. In the clearest day, when the air appears to us to be dry, there is a great deal of water in the air; you do not see it for the same reason that you do not see a solid substance when it is dissolved in water. The water is dissolved in the air; and hot air will dissolve more water than cold, just as hot water will dissolve more alum than cold water. When water gathers on our cool tumblers in hot weather, it is because the hot air all around the tumblers has so much water dissolved in it.

As crystals are often formed from solutions, it is proper to speak here of crystallization.

Hot water will dissolve twice as much alum as cold water. If you dissolve, then, as much as you can of alum in hot water, that is, make a saturated solution, when the water becomes cold half of the alum will become solid again; and in doing so it will gather in crystals upon the bottom and sides of the vessel. If you suspend a wire in the vessel of dissolved alum, as it cools the crystals will collect upon this wire. You have, perhaps, seen baskets made of alum or other crystals. They were made in this way: the basket, made of bonnet-wire, was suspended in a hot solution of alum, and the crystals formed upon all parts of the wire.

When the substance used dissolves as freely in cold as in hot water, as is the case with common salt, crystallization is produced only by evaporation. As the water goes off into the air, the crystals form.

How beautiful and curious a process crystallization is! In what exact order are the particles arranged to make such very smooth surfaces and such straight edges! They are particles, remember, that are so small that we can not see them even with a powerful microscope; and yet, in forming a crystal, each one is made by the Creator to take its right place. Sometimes the particles arrange themselves very quickly. The most familiar example we have of this is in water. Sometimes, on taking up a pitcher of water on a cold morning, a great part of the water turns all at once into crystals, which shoot across in the pitcher in every direction. If you pour out what water remains fluid, you can see the crystals. The explanation of this is easy. The water in the pitcher during the night became freezing cold, but it was perfectly still, and so the particles of the water remained motionless; but the shaking given to them by taking up the pitcher made them arrange themselves in the solid crystalline form.

We have the same quick formation of crystals, on a large scale, in every snow-storm. The clouds are the reservoirs of water from which the snow is made, the water in them being in the form of fog; and the particles of this fog are in a snow-storm continually arranging themselves in crystals, and so fall to the earth.

There are great varieties in crystalline arrangement. We will point out some of them. Mica, a mineral used for windows in stove doors, is arranged in leaves which you can peel off exceedingly thin. The sheets of mica, or isinglass, as it is commonly called, used for this purpose are really made up of very many of these thin leaves. In Fig. 43 you see the shapes of the crystals of common salt. They are cubical blocks. And in Fig. 44 you see the forms of the crystals of a very beautiful mineral called calc spar, or sometimes Iceland spar, because it was first brought from Iceland. It is composed of the same things as common chalk. You see that the crystals are not cubical, like those of salt, but they are sloping. These are but two of the very many varieties that occur in the shapes of crystals. Sometimes the same substance appears in many different forms. This is the case with gypsum, as noticed on page 102.

Fig. 43.

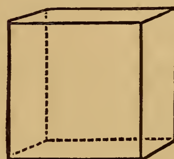
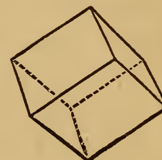


Fig. 44.



In the crystals of some salts there is water locked up and con cealed, but in some there is none. In carbonate of lime there is no water, but only carbonic acid and lime. In crystallized carbonate of soda, on the other hand, there is more of water than there is of carbonic acid and soda together. In 100 pounds of this salt there are 63 pounds of water. Yet the crystals are dry; for the water is a part of the solid substance, locked up with the carbonic acid and the soda. You can get this salt without any water in it by heating it; but the first thing it does on applying the heat is to melt in its own water. As you continue the heat you drive off this water into the air, and the powder of the salt is left behind. It is no longer crystalline; for it can not be so without its supply of water, or its *water of crystallization.* By this term we mean the amount of water which is contained by any substance when in a crystalline form. This varies in different substances. Some require no water, some a little, and some a great deal.

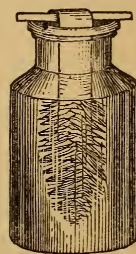
Nitrate of potash, or saltpetre, has no water in it. If it had, it might not answer so well for making gunpowder. Nitrate of soda has no water in it, and it would do for making gunpowder as well as the nitrate of potash, were it not for one thing: it gathers moisture from the air. This would not answer for powder, for powder must be kept dry. A salt which thus gathers moisture from the air is said to *deliquesce*—a word which comes from a Latin word meaning "to melt." A salt, on the other hand, which, on exposure, loses its water of crystallization, and changes from a crystal into a powder, is said to *effloresce.* Crystals that do this have a mealy powder gradually form on their surface. The word "effloresce" comes from a Latin word meaning "to flower." It is as if the mineral flowered out.

Many of the metals exist in crystals. We shall describe a beautiful experiment by which you can easily obtain lead in crystals.

There is a substance made of acetic acid (the acid of vinegar) and lead, commonly called sugar of lead, because it has a sweet taste. You must not taste it, however, because it is poisonous.

Dissolve half an ounce of sugar of lead in six ounces (twelve table-spoonfuls) of water, in a bottle. Fasten to the cork a rod or stick of zinc, and hang it in the solution, as shown in Fig. 45, on the following page. You will soon see a change taking place. The zinc will begin to have little spangles upon it, and these will gradually branch out in all directions, forming a sort of tree. This tree is made of the metal lead, and is called the lead tree. The explanation is this: the acetic acid leaves the lead and unites with the zinc to form acetate of zinc. The lead, which is separated from the acid, forms the tree, while the acetate of zinc dissolves in the water, taking the place there of the acetate of lead. It takes a day or two for the tree to be completed. If, on making the solution in the bottle it is not perfectly clear, you can make it so by adding a little good vinegar.

Fig. 45.



Questions.—Give some illustrations showing the variety as to solubility of substances. Show the necessity for the difference in regard to lime and potash. What is said of the solubility of common salt? What of the solubility of carbonate of soda and carbonate of lime? What would be the difficulty with shell-fish if carbonate of lime were very soluble? Why is it necessary for them that it should be a little soluble? How does carbonate of lime get into the sea? What is one of the causes of the hardness of well-water? What is said of silica? What is said of hot and cold water in dissolving substances? What is a saturated solution? State the difference between potash and lime in saturating water. Explain what solution really is. What is said of the solution of water in air? What of making crystals of alum? What is said of the process of crystallization? State the example given of sudden crystallization. What is said of crystallization in a snow-storm? Describe the three varieties of crystalline forms that are given. What is said of the same substance appearing in various forms? Give in full what is said of the water of crystallization. What is deliquescence? What is efflorescence? Describe the method of obtaining lead in crystals. Explain the chemistry of the operation.

CHAPTER XXIV.

WOOD. PETROLEUM.

So far, you have been learning chiefly about the chemistry of *mineral* substances, but we will now tell you something about the chemistry of *vegetable* and *animal* substances. Mineral chemistry is sometimes called *Inorganic* chemistry, and the branch of chemistry explained in the remaining chapters is called *Organic* chemistry. Most people, when the term mineral substances is used, think that solid substances only are meant; but air and water are as truly mineral substances as the crystals on the shelves of a cabinet, or the stones and rocks around you. Organic chemistry teaches about wood, sugar, alcohol, starch, gum, the substances in the flesh and other parts of animals; and since these all contain *carbon*, about which you learned in Chapter V., organic chemistry is often called the chemistry of carbon. It was formerly thought that such substances as alcohol, acetic acid, indigo, and the like, could be produced only through the agency of a living force; but we now know that these very substances can be made artificially in the laboratory.

You must not think that all organic substances can be made by the chemist. Certain substances having a peculiar structure, easily recognized by a microscope, can not be made in the laboratory. Starch is one of these, cotton is another. These are called *organized* bodies, because they have an organized structure.

We have told you already something about the chemistry of vegetables in speaking of carbon as entering into the leaves and making a part of the wood of trees. Now, wood is composed of three things: carbon, oxygen, and hydrogen. You see that it is composed of a solid united with two gases. When we make charcoal out of wood, as described to you on page 31, we decompose the wood. We send off its oxygen and hydrogen into the air by the heat of the burning, and most of the carbon is left behind. We say most of it, but not all, for some of the carbon unites with the oxygen in the combustion, and flies off as carbonic acid gas.

Though you can thus decompose wood, you can not take the ingredients and unite them so as to make wood of them. If you mix up powdered charcoal with water, you have all of the ingredients of wood together; but you can not in any way make them combine to form wood. So you have the ingredients of wood if you put charcoal into a jar filled with oxygen and hydrogen gases, but they will not turn into wood; they will remain unchanged. If you light up the charcoal before you put it into the jar, an effect will be produced, but no wood will be made; an explosion will take place, the oxygen and hydrogen uniting with great violence, forming water, and some of the oxygen uniting with the charcoal to form carbonic acid gas.

See how different this is from what we can do with some of the minerals that we have told you about. For example, take sulphate of copper or blue vitriol. This is composed of three things: sulphur, oxygen, and copper. Now, we can make the sulphur and oxygen unite to form, in the presence of water, sulphuric acid, and then this acid will unite with the copper, forming the sulphate of copper.

But although *we* can not in any way make the ingredients of wood unite to form wood, it is done in the tree. Let us see how. Much of the carbon is furnished from the air, being taken in by the leaves from the air, as you learned in Chapter VII. Then the water that comes up in the sap from the roots furnishes the oxygen and hydrogen; for water, you know, is composed of these two gases. We may say, then, that the tree makes its own wood out of charcoal and water.

Wood in every tree is composed of the same things—carbon, oxygen, and hydrogen—although the trees are so different; and there is more difference in the ways in which wood is put together in different trees than you would suppose from looking at the outside, or from seeing the wood itself with the naked eye. The microscope shows astonishing differences. In order to see these, exceedingly thin shavings, of various kinds of wood, are cut with a very sharp instrument across the grain of the wood. On examining these with the microscope, they are so much magnified that we can see just how each kind of wood is put together. In some, as the pine, there is a very open network, with here and there large round openings, while in other more solid woods the spaces are much smaller. These spaces have very great variety of arrangement in different kinds of wood, and in some the arrangement is exceedingly beautiful.

But there is still more variety in wood than we have yet told you about. There are a great many other things which are really wood besides those which people commonly call by this name. The bark of trees is wood, only in a different form from the wood which it covers, very much as chalk or the common limestone differs from marble. Hold a leaf up so that the light can shine through it. All that delicate frame-work that you see is a wooden frame-work. More than this, the skin of the leaf and all its substance are wood. The whole leaf is wood except the sap that is in it, and that which gives it its beautiful color; and what we have said of leaves is true also of flowers. The most delicate flower that you can find is made of wood; very, very fine and delicate is such wood, and yet it is wood. Every stalk of grain and blade of grass is made up chiefly of wood. Cotton or linen fibre is woody fibre.

All paper is wood. It is made, when it is fine, as writing-paper, of cotton and linen rags, and these are wood. If you tear a piece of letter-paper, and look at the torn edge through a magnifying-glass or a microscope, you will see very plainly the woody fibres pointing out in all directions from the edge. In paper these fibres are not regularly arranged as in the cotton after it is gathered, but they are mingled together in all sorts of ways, lying across each other in confusion.

All the frame-work, as we may call it, of fruits is wood. All the partitions in fruits are wooden partitions—as, for example, in the orange.

The coverings of all seeds are wood. In some of the nuts the woody substance forming their covering is very dense and hard, as in the cocoa-nut, the walnut, etc. The substance called vegetable ivory is wood very closely put together.

We put woody fibre to a great variety of uses. We build houses with it, and fill them with wooden furniture. We make ships, carriages, bridges, of wood, and in some countries even shoes are made of it. Out of woody fibre we make thread, twine, cordage, and fabrics of every variety. We clothe ourselves with it; we write and print upon it; we even eat it as part of our food; we burn it to keep ourselves warm, and to do our cooking. We spread it out in huge sheets to the wind in our boats and ships.

All the coal in the earth was once wood. Immense forests covered the earth, which, in the course of time, became buried in the earth, and were converted into coal by the action of heat under pressure. The decomposition of the wood went on very slowly, the hydrogen and the oxygen passing off for the most part, and the carbon remaining.

The change is something like that which wood undergoes when heated strongly in a close vessel, as explained in the experiment illustrated by Fig. 9, on page 32.

Some kinds of cōal are much more wood-like than others. A brown kind, which retains partly its woody structure, is called *lignite;* then we have *bituminous coal*, which burns with a smoky flame; and, finally, hard coal, or *anthracite*, which is the coal commonly burned in our furnaces and grates.

Coal is not pure carbon; if it were, we could not make any illuminating gas from it, for this gas contains hydrogen combined with carbon. When coal is heated in large iron retorts in the gas-houses, besides the gas, a substance called coal-tar is obtained, a black, sticky material of disagreeable odor, and which you would not care to have any thing to do with. Yet from this once valueless substance many of our most beautiful dye-stuffs have been manufactured, especially certain shades of violet and red, known under the name of aniline colors.

Coal buried in the earth has been heated by natural fires, in a somewhat similar manner, and this has furnished us that valuable material, petroleum. Petroleum, obtained by pumping out wells bored in the oil regions, is a mixture of many liquid and solid bodies composed of hydrogen and carbon. When it issues from the earth, it is dark-colored and ill-smelling, and must be refined by a peculiar process. This separates the petroleum into several liquids, of which the most useful are: gasolene, naphtha, benzine, kerosene, lubricating oil, and a solid body called paraffin. Gasolene is used in making "air-gas;" naphtha, for paints and varnishes, and for cleansing greasy articles; kerosene, for burning in lamps; and paraffin, in making candles.

Naphtha and benzine are very light liquids, and readily rise in vapors, which, mixed with air, make very explosive gases. When kerosene contains these substances, especially benzine, it is very dangerous. Refined kerosene is safe to burn in lamps; but in order to sell it cheap, manufacturers sometimes mix benzine with it, and this gives rise to many sad and terrible accidents.

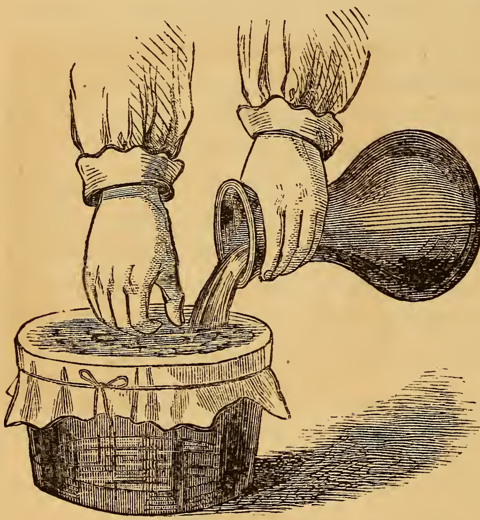
Questions.—What does organic chemistry teach? Can organic substances be made by the chemist? Name some substances having an organized structure. What is said about the composition of wood? What is done to wood in making charcoal? What is said about making wood? How is wood formed in the tree? What is said of the different varieties of wood? What of its uses? What is the origin of coal? Name the three kinds of coal. What is coal-tar? What is manufactured from it? What is the origin of petroleum? What is said of it? What are the useful materials obtained by refining it? What is said of kerosene?

CHAPTER XXV.

STARCH AND SUGAR.

Starch is a very common substance in vegetables. It is not so common as wood, for that, as you have learned, is in every part of all vegetables, from the largest trees to the smallest plants. There is more or less starch in all the vegetable substances we eat. Four-fifths of the flour of which our bread is made is starch. Most of the potato is starch. There is much of it in chestnuts, and even in horse-chestnuts it constitutes one-eighth of the whole. Arrowroot is a starchy meal, prepared from some plants that grow in marshy grounds in warm climates. Sago is a starchy substance, prepared from the pith of various kinds of palm-trees. From all this you see that a large part of the food of man is starch.

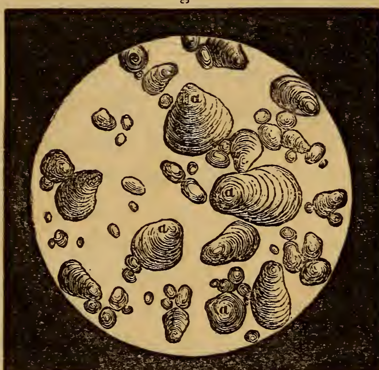
Fig. 46.



You can very readily obtain starch from wheat flour. Moisten a handful of it with enough water to make a thin paste. Put this into a piece of thick linen cloth and knead it, adding water to the paste as long as the liquid which runs through the cloth appears milky. Let the liquid in the vessel stand for some time, and a white powder will settle at the bottom. This is wheat starch. What remains in the cloth we will tell you about in the next chapter.

The starch forms grains, and each little grain, as seen by the microscope (Fig. 47), has a covering. Now, in boiling starch it swells up into a thick jelly. In this operation the coatings of the grains are broken, and the starch absorbs considerable water. This is the reason that rice, beans, barley, etc., swell so much when they are cooked. Chestnuts swell when you boil them, from the same cause.

Fig. 47.



You will be surprised to learn that starch, though so different from wood, is composed of the same elements — carbon, hydrogen, and oxygen—and that, too, in the same proportions. It is deposited in those parts of the plant where it can be used for food, in the grains or seeds, and other fruits, as in the tubers of the potato-plant.

Sugar is another substance found in many plants. All fruits that are sweet have sugar in them. Besides this, there are some plants which are designed by the Creator to make sugar for the use of man; of these the most important are the sugar-cane, the sugar-maple, and the sugar-beet. In Germany and France, the sugar-beet is largely cultivated for the manufacture of sugar.

Sugar, like starch and wood, is composed of carbon, oxygen, and hydrogen, but not in the same proportions. Although *we* can not make sugar by mixing these ingredients together, any more than we can wood or starch, yet this is done by the plants. Much of the carbon is taken from the air by the leaves, while the water comes up from the ground by the roots. The long, broad leaves, shaped much like corn-leaves, are spread out to the air to suck in, by their little and numberless mouths, the carbon from the air, so that there may be enough of this material for making the sugar. Now, as the carbon in the air comes in part from the breath of animals, it may be that some of the carbon in some of the sugar that you have eaten may have come from your lungs. If so, it flew a long way, on the wings of the wind, to the south, to get to the cane-leaf that drank it in.

In obtaining sugar from the cane, the juice is first pressed out between heavy iron rollers. This juice is then cleared of most of its impurities, and is boiled down to such a degree that the sugar will crystallize as it cools. While this crystallization is going on, a sirup trickles from the sugar, and this is molasses. The sugar crystallizes in grains, forming the common brown sugar. Further purification is required to make it into white sugar.

There are different kinds of sugar. The two most important are grape-sugar and cane-sugar. Grape-sugar is that which is found in grapes and in sweet fruits generally. Cane-sugar is that which is found in sugar-cane and other plants that are evidently designed by the Creator to manufacture sugar for our use. The cane-sugar has much greater sweetening power than grape-sugar, and therefore is more valuable. A single tea-spoonful of cane-sugar has as much sweetening power as two and a half tea-spoonfuls of grape-sugar.

The difference in composition between these two kinds is that the grape-sugar has more of oxygen and hydrogen than the cane-sugar; or, because oxygen and hydrogen are the two ingredients of water, some chemists say that grape-sugar has more water in it than the other.

Though we can not take carbon and oxygen and hydrogen, and make them into wood, or starch, or sugar, we can make sugar out of either starch or wood. "What!" you will perhaps exclaim, "make sugar out of sawdust?" Yes, exactly so. It can be done by heating with sulphuric acid diluted with water. The sawdust is first moistened with sulphuric acid, and left to stand for about twelve hours; it becomes nearly dry, water is added and the mixture boiled; the sugar is then formed. Being, however, in the form of sirup, and mixed with the excess of sulphuric acid, the latter is first removed by means of chalk, and the remaining liquid is boiled down to get the sugar. This process will be explained in Hooker's Chemistry, Science for the School and Family, Part III.

Sugar can be manufactured from rags as well as from wood; for, as you have already learned, rags are nothing but wood in a certain form.

The process of converting starch into sugar is essentially the same. But what kind of sugar can thus be made out of such cheap materials as sawdust and rags? It is grape-sugar, and not the valuable cane-sugar. If we could manufacture cane-sugar in this way, we should not need to depend so entirely on the sugar-cane for our supply.

We have told you that there is sugar in all sweet fruits; but there is no sugar in them at first. They are either tasteless or acid, and become sweet as they ripen. Before they ripen there is starch in them, and this changes into sugar.

Though we can make wood into sugar, we can not turn sugar into wood. This is done, however, by plants. Suppose we have a sugar-maple that has not been tapped by any one, what becomes of all the sugar that is in it in the spring? Does it stay there locked up for some one to get next spring? If it does, what a quantity of sugar there will be for him, for he will have all that is made in two seasons! But the sugar does not all stay there; it circulates about in the tree, and helps to make leaves and bark and wood. But that sugar should be turned into wood is no more strange than that wood should turn into sugar; and when we come to look into the whole matter, it is not so strange after all, for wood and sugar are composed of the same things—carbon, oxygen, and hydrogen. The proportions only need to be changed to convert the one into the other.

We see the same change of sugar into wood in other vegetables. Thus the sugar-beet and turnip are sweetest when gathered early. If allowed to remain growing too long, the sugar is changed into wood, and they become, therefore, tough and tasteless. So, also, if grass be left to grow too long, the starch and sugar in it turn to wood, and the hay is not so sweet and nutritious as it would have been if gathered earlier.

We can make charcoal from sugar as well as from wood, since it is composed of the same elements. We can do it simply by heating the sugar; but a prettier way to do it is this: Put a table-spoonful of strong sirup, made with loaf-sugar, into a tumbler set in a large plate, and pour upon it a little good sulphuric acid. The acid sets free the charcoal, producing considerable heat. This makes a brisk bubbling-up, even over the sides of the tumbler. After the tumbler gets cool, pour the contents into the plate, and you have a specimen of *sugar-charcoal.*

Questions.—What is said of the abundance of starch in plants? Mention some of the vegetable substances in which it is found. What is arrowroot? What is sago? How can you obtain starch from wheaten flour? What sort of a substance is starch? What effect has boiling upon it? What is said of the composition of starch? Where in plants is it deposited? What is said of sugar in vegetables? What is the composition of sugar? What is said about sugar in plants? How is sugar obtained from sugar-cane? What is molasses? What are the two kinds of sugar, and how do they differ? What is said of making sugar from wood? From rags? What of making sugar from starch? What kind of sugar is made from these substances? Why can not cane-sugar be made in this way? What is said about sugar in fruits? What about the change of sugar into wood in the sugar-maple? In vegetables? What is said of sugar-charcoal?

CHAPTER XXVI.

GLUTEN AND THE FOOD OF ANIMALS.

You see that vegetable substances are mostly made of carbon, oxygen, and hydrogen; but animal substances, flesh, skin, hair, nerves, etc., are made of these same things, with another added, viz., nitrogen. It is this gas that makes the great distinction between animal and most vegetable substances.

It is the nitrogen compounds in part that give the peculiar strong odor which we smell whenever any animal substance is burned. Wood, cotton, linen, etc., give out but little smell when burned; but let any woolen thing, or hair, or leather be burned, and the odor is disagreeable and strong: and it is very much the same in all these cases.

As nearly all substances which are peculiar to animals have nitrogen in them, there must, of course, be some nitrogen in their food, for without this they would droop and die. It is the food that makes the blood, and the blood, as you learned in the Second Part of the Child's Book of Nature, is the building and repairing material of the body. You can see, then, that if no nitrogen be furnished to the blood, one of the four great materials for building and repairing will soon be spent. The body will, therefore, in a little time, show this great want, and get out of repair; and, if it remain long in this condition, it will die. To repair the body without nitrogen would be very much like repairing a brick-wall without brick, filling up breaches in it with mortar alone.

Now, you can readily see where some animals get that part of their building and repairing material which we call nitrogen. Lions, tigers, dogs, cats, etc., eat animal food, and there is nitrogen always in that. But how is it with horses, cows, sheep, etc.? Where do they get their nitrogen? They eat no animal food, and the vegetable substances that we have told you about — wood, starch, and sugar—contain no nitrogen. There is a plenty of nitrogen all around them in the air, and they breathe it continually into their lungs; but not a particle of this gas gets into the blood.

How, then, do the vegetable-eating animals get their nitrogen? We will tell you. You remember that, in describing the method of obtaining starch from wheat flour, we said there was a substance left in the linen cloth; this substance we call *gluten*—a very glutinous, or sticky, substance. This portion of the flour contains nitrogen. While the starchy part is composed of carbon, oxygen, and hydrogen, the gluten is composed of these and nitrogen also.

It is the gluten of the flour that gives firmness to bread. If it were composed of starch alone, the bread would crumble very easily. It is for this reason that rice griddle-cakes break so readily when there is not enough flour mingled with the rice. The gluten of the flour is needed to hold together the starchy rice.

There is another substance in the flour that contains nitrogen. It is called *albumen*, from the Latin word *albus*, white.

It is like the white of egg, and is really about the same thing. There is much less albumen in flour than of gluten.

In the grain of wheat, then, we have three substances—starch, gluten, and albumen. There is much more starch than gluten, and the albumen is very small in amount.

There is another substance containing nitrogen, found in many vegetables. We call it *casein.* It is nearly the same thing as the cheese which is contained in all milk, and which makes the curd. There is a great deal of this substance in vegetables that grow in pods, as pease, beans, etc.

The three substances in vegetables that furnish animals with nitrogen are, then, gluten, albumen, and casein. They are called *nitrogenous* substances. The most abundant is gluten, which occurs especially in the grains used so extensively for food—wheat, rye, buckwheat, barley, oats, Indian corn, etc.

Starch and sugar have no nitrogen in them, and carbon is their most important element. They are said, therefore, to be *carbonaceous* substances, in distinction from the nitrogenous. Now, these substances alone can not support life for any length of time. Some dogs which, by way of experiment, were fed upon nothing but starch and sugar, languished and died. It was for want of nitrogen.

There is another class of substances, found both in vegetables and animals, which are carbonaceous, and have no nitrogen in them. They are the oils and fats.

It is the nitrogenous substances in our food that build up and repair the body. Of what use, then, are starch, sugar, and the fats? Their use is chiefly, if not wholly, to keep up the heat of the body. They are a part of the fuel, which is burning up everywhere with the oxygen that is in the blood.

The capacity of an article of food to nourish the body or promote its growth is supposed to depend on the amount of nitrogen there is in it. Rice is not very nutritious, because it contains a great deal of starch and very little gluten. The common grains, as wheat, rye, etc., are among the most nutritious vegetable substances, for they contain much gluten. There is a great deal in the coverings of the grains, which, broken up, make the bran. Therefore bread made from bolted flour is not so nutritious as that made from unbolted flour. Pease and beans are very nutritious, because they contain so much of that nitrogenous substance, casein, or vegetable cheese. The cabbage is one of the most nutritious of vegetables, for it has even more gluten in it than the grains.

There is some gluten in leaves and grass, but not so much as in the grains. The horse, therefore, though he may thrive upon hay alone when idle, must have some kind of grain when he is worked. The wear and tear of the muscles in working makes a good supply of nitrogenous food necessary for repair.

For the same reason, the food of a laboring man should be richer in gluten than that of a man who lives at his ease. In the repairing that his muscles require after the wear and tear of labor, it will not do to supply food that is composed only of carbon, and oxygen, and hydrogen; there must be a good quantity of nitrogen. If the laborer, therefore, should live chiefly on rice, as in China, or on potatoes, as is often the case in Ireland, the machinery of his body would not be well repaired, and he would become weak. He must have such food as bread and meat, with his potatoes, rice, etc., in order to get enough nitrogen for growth and repair.

Bread is called the "staff of life." Still better is it when we add to it the fatty carbonaceous substance, butter. Milk is such a combination of nitrogenous and carbonaceous substances that it is a *complete* food by itself, as is shown by the fact that children often live a long time on this article alone.

Vegetable substances contain nitrogen for the very purpose of supplying it to animals. Animals must have it in their structures—in their muscles, nerves, bones, skin, brain, etc. But vegetables do not need it in their structures. Wood does very well without it, though bone and muscle can not. Since, then, vegetables do not need it in their structures, Providence does not put it there, but makes it go into grains and other parts of vegetables where animals can readily get at it, and use it in their food.

Questions.—Of what are most vegetable substances composed? Animal substances? What is said of the odor of animal substances in burning? What is said of nitrogen in the food of animals? What about gluten? What about gluten in bread? What about rice cakes? What of albumen? What of the three substances in wheat? What is said of casein? What are *nitrogenous* vegetable substances? Which is the most abundant of them? What are *carbonaceous* vegetable substances? What is said of their power to support life? Of what special use are starch, sugar, and the fats? Upon what does the nourishing power of substances depend? What is said of the grains in this respect? What of unbolted flour? What of pease and beans? What is said of animals being able to live on grass? What of the necessity of nitrogenous food for the laborer? What about having the two kinds of food mingled? What is said of bread? Of milk? About nitrogen in animals and vegetables?

CHAPTER XXVII.

FERMENTATION. VINEGAR.

You have heard the word *ferment* often used, but have you ever thought exactly what it means? When cider is first made, it is the mere juice of the apples. It is not fermented. It works, or ferments, afterward. So, also, wine is the fermented juice of grapes.

What is done by the fermentation? What is the change that is produced? It is a change in the proportions of carbon, oxygen, and hydrogen, of which the substances that ferment are composed; or, rather, it is a change in one of these substances. The substance which is changed is sugar. All those liquids which form intoxicating drinks by fermentation are composed chiefly of sugar dissolved in water, a flavor being given to the sirup by the plant from which it comes. Thus, the change produced in the juice of apples is only in the sugar. The water in which the sugar is dissolved is not changed at all. So, also, grape-juice is sugar dissolved in water, with a flavor peculiar to the grape, and it is the sugar only that is changed in the fermentation.

Notice now what the change produced in the sugar is. The sugar, so sweet to the taste, is changed into a substance called alcohol. It is so fiery that it must be diluted before it can be drunk. The strongest brandy is more than half water.

When sugar is transformed into alcohol by fermentation, a change of the proportions of the carbon, oxygen, and hydrogen takes place, but nothing is added. On the contrary, some of the carbon and some of the oxygen of the sugar leave it, forming by their union carbonic acid gas, which flies off into the air. Thus, fermentation produces from the sugar two things—alcohol and carbonic acid.

This change in the sugar is caused by yeast. But how? Does the yeast unite with any thing in the sugar to form the alcohol, as oxygen unites with iron to form rust? No; it simply forces the sugar to separate into two things, carbonic acid and alcohol. It is merely the instrument by which the sugar is split into two parts, and is itself unchanged.

The working of the juice of the grape, or of cider, is caused by the gluten in them, which acts much like yeast. Either one of the nitrogenous substances, gluten, albumen, or casein, may act as a ferment.

The fermentation of bread is really the same thing as the fermentation which makes drinks intoxicating. The yeast turns the sugar in the dough into alcohol and carbonic acid, and these two together puff up the bread in their efforts to escape. The alcohol flies off in vapor in the oven, and escapes into the air.

In uncorking bottles of beer and cider there is a great escape of gas, making a lively foam. This gas is carbonic acid. It is made in the bottle by fermentation, and, so long as the liquid is confined by a tight cork, the gas is imprisoned there among the particles of the liquid; but, the moment the cork is loosened, the gas escapes.

The production of alcohol from the grains, barley, rye, etc., and from potatoes, is different from its production from apple-juice and grape-juice. In the grains there is a great deal of starch and but little sugar, and this starch must be first changed into sugar before alcohol can be produced. Thus, in making beer from barley, the first thing is to make into sugar as much as we can of the starch in the barley. It is done in this way: The grain is moistened and left in heaps; it sprouts, and, in doing this, much of the starch is turned into sugar, so that the barley has a very sweet taste. The *malt*, for so this sugared barley is called, is now dried, and, after being bruised, is put into the boiler with water; after boiling sufficiently, the liquor is drawn off into vats. It is now a sugary solution, and, the yeast being added to it, produces the alcohol from the sugar by fermenting. When the mixture is boiling, hops are put in to give the beer a bitter flavor, and to prevent its becoming sour.

When cider stands in a barrel having the bung-hole open, it gradually turns to vinegar, undergoing another kind of fermentation. Vinegar is a mixture of water and a substance called acetic acid, together with small quantities of sugar, gum, and coloring matters. It is the alcohol in the cider which is converted into acetic acid, and the latter gives the vinegar its sour taste. The alcohol will not change of itself into vinegar; there must be a ferment or yeast to produce this fermentation as well as that which forms alcohol. In making vinegar from cider in the common way, the work is done by the same gluten that was in the apple-juice and turned it into cider.

Sometimes vinegar is manufactured in a rapid manner. It

Fig. 48.

is done in barrels, as shown in Fig. 48. The barrel is represented in the figure as partly open, that you may understand the arrangement. A mixture of alcohol and water, having a little yeast in it, is allowed to drip through small holes in the shelf in the upper part of the barrel. The barrel is filled with loose shavings, and air is admitted through holes. The oxygen of the air unites with the alcohol as it trickles down through the shavings, and turns it into vinegar. The object of the loose shavings is to spread out, as we may say, the alcohol, so that the air can come freely to every particle of it.

The amount of acetic acid in vinegar is very small; a hundred gallons of vinegar contain only from two to five gallons of the acid.

Questions.—What is said about cider and wine? What kind of change is produced by fermentation? What substance in the fermenting liquids is changed? What kind of a substance is formed from it? What two things are produced in the change, and how? In what way does yeast change it? How is the change produced without yeast in making cider and wine? What takes place in the fermentation of bread? Explain the effervescence of bottled cider, beer, etc., when the cork is drawn. In making alcoholic drinks from barley, rye, etc., what change must first be produced? Explain the making of malt. How is the alcoholic liquid made from this? What is vinegar made up of? What is done to the alcohol to change it to acetic acid? What effects the change in the vinegar fermentation? Describe and explain the quick mode of making vinegar. How much acetic acid is there in vinegar?

CHAPTER XXVIII.

VEGETATION.

EVERY plant comes from a seed. When the seed is put into the ground, a root shoots downward into the earth, and a stalk shoots upward into the air.

Observe how the root and the stalk are made. They are not made as crystals are. Particles are not laid on, layer after layer, as in the growth of a crystal. There is no life in a crystal, but there is in a seed. It is this life that forms the plant, and it has its own way of doing it. As it builds the stalk and root, it forms channels, or tubes, as it works along; but there are no such tubes in a crystal.

Through these tubes the sap goes everywhere in the plant. This is true of every plant, from the smallest to the largest. Look at some very large and high tree. The life in a little seed gave it birth. It pushed up the stalk a little higher and higher, making tubes in it all the while; and now that it reaches up so high, the sap goes up from the roots, in these tubes, out to the very ends of its myriad of leaves.

Let us see now of what the seed from which all this comes is composed. It is mostly starch and gluten. But both of these substances are insoluble. Of what use, then, can they be in growth, when they can not be carried up in the sap that circulates in the tubes? Unless they can be rendered soluble, they can be of no use—they must remain just there in the seed. As the seed becomes moist, a chemical change takes place; the gluten is made soluble, and the starch is changed into sugar. So, as fast as the channels are made in the upshooting plant, the sap, with gluten and sugar dissolved in it, mounts up in them.

All this is merely to start the growth of the plant. When the little root is formed, and the stalk reaches the air and puts out leaves, the seed has done its work. Its gluten and starch are used up, and the plant now gathers all its materials for growth from the soil and the air. It must have carbon, oxygen, hydrogen, and some nitrogen. It obtains from the air a large part of its carbon, taking it in at every pore in its leaves. Its oxygen and hydrogen it gets mostly from the water that comes into the mouths of the roots. The plant gets its nitrogen from the ground, which contains several substances that supply it. One is ammonia, which, as you learned on page 77, is composed of nitrogen and hydrogen. There is a great deal of this substance in some fertilizers.

The frame-work or structure of the plant is composed almost entirely of carbon, oxygen, and hydrogen, while the nitrogen occurs chiefly in the seed or grain, where it is deposited for the use of man and other animals. Besides these four substances, some others are found in vegetables, but in a much smaller amount. Silica has been mentioned as occurring in stalks of grain; sulphur occurs in mustard and in the onion; and very small quantities of phosphorus, iron, lime, potash, etc., are also found in plants. All these are carried up in the sap through the channels mentioned in the first part of this chapter.

Now, think what sap is. Most of it is water, and this contains in solution the various substances above mentioned. Water, then, not only furnishes the plant with oxygen and hydrogen, but it is the means by which the other substances needed by the plant are carried about in its channels or tubes to the very ends of the leaves. Some of the water remains in the plant, giving its oxygen and hydrogen to it to help form wood, starch, gluten, sugar, etc.; but most of it is breathed out into the air through the little pores in the leaves.

Juicy fruits contain a great deal of water: the water-melon, you know, seems to be nearly all water, with a little sugar dissolved in it. When wood is just cut, it is said to be green; that is, it is full of sap. This prevents its burning well; but if it be exposed to the air, this water passes off, and the wood becomes dry.

When wood is burned in such a way that there is an abundant supply of oxygen, nothing but ashes remains. These have but little bulk compared with the wood. Only one or two pounds of ashes are obtained from a hundred pounds of wood. What has become of the remainder, the ninety-eight pounds of wood? It has gone off into the air. As a large part of the wood comes from the air, so most of it, in burning, returns to the air. Much of what passes off is water, for even what we call dry wood contains considerable water. This passes off as vapor. Then most of the carbon of the wood, uniting with oxygen, flies off as carbonic acid. Some of the oxygen of the wood is disposed of in this way, and some of it unites with the hydrogen of the wood to form water, which goes off as vapor. If this were all, the smoke would not be visible, for you can not see either vapor or carbonic acid gas; but some of the carbon goes up in little particles, and these make the smoke.

What is really the composition of ashes? They are composed of potash, silica, lime, iron-rust, etc. These substances are found in different proportions in the ashes of different plants. Thus there is more silica in the ashes of straw than in those of common wood. There is much potash in the ashes of wood, and for this reason they are used for obtaining that substance for making soap, as noticed on page 109.

Let us look a little more at what plants get from the ground to make them grow, and how they do it. They get all the different ingredients, except carbon, from this source. Most of this they get from the air, but some of it comes from the ground. They get, then, from the ground all their oxygen, hydrogen, and nitrogen, and part of their carbon, and, besides these, small quantities of the various other things which they need—as potash, lime, iron, sulphur, phosphorus, etc.

Now, much of all these ingredients comes from the decay of plants. Every year great quantities of dead leaves and other parts of plants become a part of the earth, and help to form the plants of another year.

It is thus that decay and death furnish material for new life. The living beauty that feasts our eyes in the spring comes, to a great extent, from what fell to the ground and died the previous year; and not only so, but that which in its putrefaction offends our sense of smell, becomes a part of the plants which, with their leaves and flowers, so delight our eyes, and of the fruits which are so pleasant to our taste. The nitrogen, which is one of the ingredients of the ammonia which smells so strongly in the manure of the stable, goes up the channels of the wheat-stalk, and helps to make the gluten of the grain, and as you eat it in the bread it helps to form the substance of your body.

Some substances are composed of only two of the chief ingredients of plants, carbon and hydrogen. To this class belong the oils of orange-peel, lemon, and pepper. The oil of turpentine is also one, as well as caoutchouc, or India rubber.

Other oils are composed of three of the four grand ingredients of plants, viz., carbon, oxygen, and hydrogen. Among these are the oils of peppermint, valerian, anise, orange-flowers, rose-petals, etc. Camphor, also, is composed of these three ingredients.

Some oils have considerable sulphur in them, as oil of mustard, onion, asafetida, etc. You know that a spoon, if left in mustard, becomes dark colored. This is because the sulphur in the mustard unites with the silver to form a sulphide of silver.

There are various acids in plants; these are composed of carbon, oxygen, and hydrogen in different proportions. Tartaric acid, for example, is the peculiar acid of grapes; malic acid occurs in apples, pears, and some other fruits; oxalic acid in sorrel; citric acid in lemons, oranges, currants, etc. These various acids are combined with potash, soda, lime, and other bases; tartaric acid, in the juice of the grape, is combined with potash, forming a salt called cream of tartar; this substance collects upon the inside of wine casks, depositing from the wine.

There are many different coloring substances in vegetables, as indigo, the coloring matter of logwood, of madder-root, etc. They are composed, like the acids, of carbon, oxygen, and hydrogen, or of these with nitrogen.

Another and interesting class of substances occurring in plants must yet be mentioned; we refer to the so-called alkaloids—quinine, morphine, and the like. Quinine, together with a number of similar bodies, is obtained from the bark of the *cinchona*, a tree cultivated chiefly in South America: it is a very useful medicine. Morphine comes from opium, theine from tea and coffee, strychnine from nux vomica, nicotine from tobacco. The two substances last named are among the most deadly poisons known: less than a drop of nicotine placed on the tongue causes instant death.

Questions.—What takes place when a seed is put into the ground? How are the root and stalk made differently from crystals? What is said about the sap in plants? What is said about a large tree? Of what substances is a seed composed? What change is needed in these, and how is it effected? What becomes of the seed? After the seed is gone, from what is the plant nourished? What materials of growth must it have? How does it get its carbon? How its oxygen and hydrogen? How its nitrogen? Of what elements are the structures in plants made? Where in plants is nitrogen deposited, and for what purpose? Mention some other substances that are in some plants. What is sap? What is said of the uses of the water in sap? When wood is burned, how much of it becomes ashes? What becomes of the rest? Why is smoke visible? What substances are in ashes? What do plants get from the ground? What is said of decay as furnishing materials for growth? What is said of putrefying substances? Mention some substances composed of carbon and hydrogen only. What oils are composed of three of the grand elements? What oils have considerable sulphur in them? What is said of vegetable acids? What of coloring substances? From what is quinine obtained? From what morphine, theine, strychnine, and nicotine?

CHAPTER XXIX.

HOW FOOD MAKES ANIMALS GROW.

The blood is to an animal what the sap is to a vegetable. The sap is water, containing in solution whatever is necessary to the growth or building-up of the plant; and so the blood is water, containing in solution whatever is necessary to the growth and nutriment of the animal.

About four-fifths of our blood is water; that is, in every five pounds of blood there are four of water. You will, of course, want to know what substances are dissolved in this; that is, what make up the other fifth of the blood. They are carbon, oxygen, hydrogen, nitrogen, chlorine, sodium, potassium, calcium, magnesium, iron, phosphorus, and sulphur.

These substances, you remember, are elements, not compounds. But they do not appear as elements in the blood. They are combined in various ways. For example, the iron is united with some of the oxygen, forming oxide of iron, and some of this oxide is united with phosphoric acid, making phosphate of iron. So most of the chlorine is united with the metal sodium, forming common salt. About one-third of that part of the blood which is not water is albumen. This closely resembles the albumen of many vegetables, and is likewise composed of the four grand elements, carbon, oxygen, hydrogen, and nitrogen.

How do all these different substances get into the blood? They come from the food we eat. All that part of the food which will serve to nourish the body is absorbed by the stomach, and is put into the blood and becomes a part of it. It is exactly as the little mouths in the roots of a plant suck up from the earth what is proper to go into the sap. The fact that the root of a plant and the stomach of an animal thus perform similar duties is fully illustrated in Chapter IV. of the Second Part of the Child's Book of Nature.

But all the substances in our blood are not always in our food. How is it, then, that the blood is always supplied with them? It is because the food contains the material of which these substances are made. Chemical operations go on in the stomach; it is a sort of chemical laboratory. For instance, you eat, in one way and another, considerable sugar; but there is no sugar in the blood. How is this? Is all this sugar lost? No; it is all used, but it does not go into the blood as sugar; it helps to make some other things that enter the blood.

All substances which enter the stomach are not completely decomposed, however; salt is one of these: it forms part of our food and is contained in our blood.

Oxygen, the lung-food mentioned on page 15, does not enter the blood from the food solely; indeed, a large part of it goes in by the lungs when we breathe.

All the different parts of the body, as we told you in Chapters I. and II. of the Second Part of the Child's Book of Nature, are made from the blood. For this purpose the blood, containing all the different substances mentioned, goes or circulates throughout the body; and the materials needed for building are used just where they are wanted. For example, where it is necessary to make bone, the materials for bone are taken from the blood, and are arranged so as to make the bone of the right shape. Phosphate of lime, one of these materials, is in the blood, all ready for use.

You learned on page 95 that the bones of animals are made chiefly of phosphate of lime, a salt containing the three ingredients, phosphorus, calcium, and oxygen.

This bone material enters the body through the food eaten, and so gets into the blood, and goes to the bones, where it is needed to make them grow. A certain amount of phosphate of lime occurs in both animal and vegetable food; a small quantity also is found in milk.

You see, then, that it is with the phosphate of lime in our bones as it is with the carbonate of lime in the shells of oysters and other shell-fish, in the stony skeletons of coral animals, and in the egg-shells of birds. The building material is swallowed, and, going into the blood, is carried in it to where it is wanted for building.

Think, now, whence came all of the carbonate and phosphate of lime contained in the bones and shells of animals. They came from the rocks. But how did these substances get from the rocks into your bones? A great deal of breaking-up, grinding, etc., was necessary for this. The rocks are crumbling and falling to pieces all the time, from the influence of frost and water and air. Then the soft, broken material mixes with the earth, and becomes very finely divided. Particles of it, therefore, continually get into plants in the sap which the roots suck up. If you eat vegetables, then, or the meat of an animal that has eaten vegetables, you introduce into your stomach, and so into your blood, some of the phosphate of lime derived from the rocks.

In like manner, where nerve is to be made, those materials are taken from the blood of which nerve is composed; and the same is true of all other parts of the body. Once in a while nature makes a mistake in this matter. For instance, bony substance is formed in some part where it is not wanted, as in the arteries or in the heart. This causes disease. But, generally, every thing is put in the right place.

Brain and nerve are composed of a variety of substances—fatty substances, albumen, phosphorus, sulphur, potash, lime, magnesia, etc. Phosphorus is an essential ingredient of the brain; that is, the brain can not do without it. We have heard students recommended to eat freely of eggs, because they contain considerable phosphorus. We do not believe, however, that this would make a dull scholar bright. Something else besides phosphorus is needed for that.

Hair, feathers, bone, and nails contain sulphur and silica, combined with the other ingredients.

There is iron in the blood. It is in the substance that gives the red color to this fluid. There is also a very little of it in the hair, helping, with the silica, to give it strength. Exactly of what use it is in the blood we do not know. When persons are pale and weak they have not enough of it in the blood, and they should take medicines containing iron.

You have learned what a variety of substances occur in the blood. Now, when one eats a variety of food, it is easy to see how all these various substances are furnished to the blood. But how is it with a child that lives only upon milk? Can there be mingled together in that white fluid all the substances mentioned? If they were not, there would be something missing in the building-up of the body. If, for example, there were no phosphate of lime in milk, the bones of the infant living on milk would grow, but they would be soft, and would bend very easily, since it is the phosphate of lime that makes them hard and rigid. Milk contains this, and all the other substances required for the growth of the body. It contains all the nutritious substances which can be gathered from both meats and vegetables.

Questions.—Give the comparison between sap and blood. How much of the blood is water? What elements are in the blood? Mention some of the combinations of these in the blood. What is said of the albumen in the blood? How does the blood get all the substances that are in it? Give the comparison between the stomach of the animal and the root of the plant. How is it that there are some substances in the blood that are not in the food? What is said of the sugar that we eat? What of salt? What is said of the circulation of the materials for building different parts of the body? What of making bone? Of what are bones composed? Whence come the lime-salts contained in bones? What are the substances in brain and nerves? What is said of eating eggs? In what animal structures does sulphur occur? What is said of iron in the blood? What is said of milk?

CHAPTER XXX.

CONCLUDING OBSERVATIONS.

You have learned in this little book that the whole world is built up chiefly of a few elements. In fact, there are but sixty-three elements, and of these about fifty are metals. Most of these exist in small quantities. A few of them are very abundant, as iron, calcium, sodium, aluminium, copper, lead, etc. But the most abundant substances in the world are not metals. They are oxygen, carbon, nitrogen, hydrogen, silicon, sulphur, chlorine, etc. Nearly, if not quite, one half of the world is a gas — oxygen. And the four grand elements used in the making-up of the earth are oxygen, carbon, hydrogen, and nitrogen. Three of these are gases. Water, the liquid present in almost every thing, is composed of two of them. All living substances, vegetable and animal, are essentially composed either of three of them or of the whole four.

Although the number of the chemical elements is thus limited, the variety of the substances formed by their combinations is immense: this variety is increased by the fact that two or more elements may combine in several proportions, as, for example, oxygen and nitrogen, which form five compounds, differing widely in their characters. In living organisms we have most wonderful examples of the Creator's power in producing an enormous variety of substances from a very few materials.

In the latter case, the variation in form and properties is believed to be owing to variation in the arrangement of the particles of which the substances are composed.

Oxygen combines with all the elements but one. With many of them it unites very readily, with some eagerly; but with others, as gold, platinum, etc., it unites only when forced to do so, and when it is combined with them it is easy to cause them to part company.

Let us recall a few of the combinations which oxygen forms. With hydrogen it forms the most abundant of all compounds, water. Mixed with nitrogen and carbonic acid gas, it forms the most abundant of all mixtures, the atmosphere. It forms, with the metals, oxides, a very numerous class of substances. By combining with nitrogen, sulphur, phosphorus, chlorine, silicon, etc., and the elements of water, it forms acids. One of these oxides, silica, is one of the most plentiful hard substances in the earth, being in the granite and many other rocks, and constituting, for the most part, all the sand of the land and sea, and a large portion even of the fertile earth. Then we have oxygen in all the potash and lime, and in their carbonates; the carbonates of lime in the forms of limestone and chalk and marble being very abundant substances, sometimes even forming mountains. Besides all this, oxygen is one of the chief ingredients in vegetable and animal substances.

But you see the importance of this element not only in its abundance, but also in its active agencies. It is no laggard in the chemical movements which are everywhere going on; it is a lively, busy agent. It is the grand supporter of combustion, keeping every fire and light burning. It maintains the life of all animals by entering the lungs continually, and it conveys away carbon from their bodies to the leaves of plants by uniting with it to form carbonic acid. It rusts the metals wherever it can get hold of them, and it has such an affinity for some of them that they can never be found except in union with oxygen.

The changes in the forms of matter from solid to gaseous or liquid, and the reverse—changes in which oxygen commonly is so busy—are very wonderful when we look into them. Thus, in the burning of wood, the oxygen of the air unites with the carbon and hydrogen of the solid wood, forming the gas carbonic acid, and water, which flies off with the gas in vapor. From one hundred pounds of wood, as already stated on page 163, we usually obtain but about two pounds of ashes. The ninety-eight pounds, which are water and carbonic acid, have flown off into the air. What becomes of them? Let us trace their movements. The water gathers in the clouds to fall to the earth, or settles upon the ground in the form of dew. In whatever way it comes to the earth, it there goes to work again, and works chemically, for some of it finds its way into the roots of plants, and helps to form their substance by combining with carbon and nitrogen. That part of the ninety-eight pounds which is carbonic acid floats off to be absorbed by leaves, in order to furnish carbon, by chemical operations, to the plants and trees. The oxygen that has thus conveyed, as we may say, the carbon to the leaves, returns again, in the air, to the lungs of animals; and some of the carbon thus furnished to plants comes back also to animals in the food which they eat, to repeat its chemical work in them.

This leads us to remark that much of the matter in the world is constantly circulating back and forth between animals and vegetables and the earth, and in this circulation it is all the time changing. The grand means by which this circulation is carried on are air and water. These are everywhere in motion, and they carry with them a great many substances wherever they go. For example, the air takes the carbon from our lungs, and carries it aloft for the leaves to take in, and brings back to our lungs the oxygen that the leaves breathe out. As an example of the agency of water in this circulation, you have seen how it dissolves the carbonate of lime from the rocks and the earth (Chapter XVIII.), and carries it into the sea for the shell animals to use in the construction of their shells. So, also, water brings the silica to the grasses and grains, that it may be sucked up by their roots. In these and many other ways, air and water are ever busy distributing substances, solid as well as liquid and gaseous, in every direction; and they thus have more influence than any other agents in carrying on the grand chemical operations of the world. They are not only continually changing themselves, but they produce changes in other substances by bringing them together so that they can act upon each other.

The world is emphatically a world of change; and in the changes that take place there is no loss, no destruction of material. When any thing burns up, as we express it, there is no destruction of any substance; there is merely change from one form to another, and what seems to vanish in air soon re-appears in the solid forms growing up all around us. So, when decay takes place, there is no loss of a single particle of matter, but chemical force is simply bringing about new combinations and arrangements of the particles of the decaying substance. Chemical force is at work throughout the universe, not destroying, but pulling to pieces only to rebuild again, and in all its manifold operations reflecting the wisdom, love, and power of an Omnipotent Being.

Questions.—How many elements are there? How many of them are metals? Name some of the most abundant of them. What are the most abundant of all the elements? What are the four chief elements? Which of them is the most abundant? What is said of the variety of the substances formed by the combination of the elements? Give what is said of some of the combinations of oxygen. What is said of its activity as an agent? State what is said of the changes that take place in the combustion of wood and in consequence of it. What is said of the circulation of matter? What is said of the changes that chemistry is effecting in the world?